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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXVIII.—*A New Devonian Formation in Colorado;* by Whitman Cross.

The existence of Devonian formations in the San Juan region of Colorado was first established through the discovery of invertebrate fossils by F. M. Endlich of the Hayden Survey, during the summer of 1874.* The Devonian character of the fauna discovered by Endlich was announced by F. B. Meek,† later questioned by C. A. White‡ and R. P. Whitfield,§ reaffirmed by C. Schuchert,** and finally established by G. H. Girty†† upon the basis of extensive collections from many localities obtained during the survey of the San Juan country under the direction of the writer. The limestone formation, from which Endlich collected a few fossils and which has yielded the extensive fauna studied by Girty, was described by A. C. Spencer,‡‡ at the time the writer's assistant in the Colorado work, as the *Ouray Limestone.* It has been found, since the cited publications by Spencer and Girty, that the upper part of the lithologic unit, the Ouray limestone, contains a Mississippian Carboniferous fauna. This has now been described by Girty,§§ in his review of the known Carboniferous

* Ann. Rep. U. S. Geol. and Geog. Survey, etc., for 1874, pp. 211–214.
† Bull. U. S. Geol. and Geog. Survey, etc., 2d Ser., No. 1, 1875, p. 46.
‡ Bull. U. S. Geol. and Geog. Survey, Terr., 2d Ser., No. 1., 1875, p. 47.
§ U. S. Geol. Survey, Monog. XII, 1886, p. 56.
** Bull. U. S. Geol. Survey, No. 87, p. 166.
†† Devonian fossils from Colorado. The Fauna of the Ouray Limestone. U. S. Geol. Survey, 20th Ann. Rep., Pt. II, 1900, pp. 25–81.
‡‡ "Devonian Strata in Colorado," this Journal (4), ix, 1900, p. 125.
§§ "The Carboniferous Formations and Faunas of Colorado;" Profession. Paper No. 16, U. S. Geol. Survey, 1903.

invertebrates of Colorado. The Ouray limestone has been studied in several quadrangles of the San Juan region, the original locality at which its Devonian fauna was first discovered by Endlich has been revisited, and its position as a well determined unit in the Paleozoic section of Colorado must be considered as established. The present paper refers to the immediately underlying formation, in which Endlich found fish remains, and which is now for the first time given a distinctive name.

The locality at which Endlich first observed the Devonian strata lies upon the southern slope of the Needle Mountains, about 10 miles east of the Animas canyon at Rockwood, and on the western rim of the Vallecito canyon. The beds are very near the base of the Paleozoic section which dips southerly under the influence of the post-Laramie domal uplift about the Needle Mountains center. Erosion has removed the sediments over a large area, in places exposing the coarse-grained granite upon which they rest and here and there leaving tongues or isolated patches of the lower formations.

The Devonian invertebrates were found by Endlich at a triangulation station, obscurely referred to in his report as "Station 48," which is easily identifiable from the topographic report of 1874 as the point of elevation 12,305 feet, according to the Hayden map, directly overlooking the Vallecito canyon and a little south of the boundary of the Needle Mountains quadrangle. A stone monument still stands at the point, upon a remnant of Ouray limestone very rich in fossils and near the base of the formation. A branch of the Vallecito, heading west of the point, cuts it off from the main sloping mesa of sedimentary rocks, which begins a half mile to the southwest. In the absence of sufficient geographic terms for descriptive purposes, the writer proposes the name "Devon Point" for this knoll capped by Ouray limestone, the "Station 48" of the Hayden survey, which must become a classic spot in the discussion of the Colorado Devonian. The name Endlich Mesa has already been given, upon the Needle Mountains topographic map, to the gently dipping surface of granite and thin overlying Paleozoic beds which lie between the Vallecito and the Florida rivers, and is terminated by the headwaters of the latter stream. Devon Point lies on the eastern edge of Endlich Mesa.

Below the triangulation monument of Devon Point there are but about 25 feet of the Ouray limestone. Intervening between the limestone and the granite are two distinct formations referred to by Endlich* in the following terms, which (as to the upper

* Loc. cit. pp. 211, 212.

one) specifically apply to the exposures southwest of Devon Point about one-half mile, where the sediments reappear beyond the stream above mentioned, which has cut through them into the granite. They apply as well, however, to the strata at Devon Point.

"Resting immediately upon this granite, which showed a very marked stratification, conformable with that of the superincumbent sedimentary beds, a white to red and brown quartzite was found. At some points the contact of the latter with the granite was so intimate that specimens could be obtained, showing both the granular quartzite and the coarse-grained granite on the same piece. No definite relation of the colors exhibited by the quartzite could be established, save the general rule that the nearer it was to the underlying metamorphic rock, the more intensely it was colored." * * "Above the quartzite is a thin stratum of yellow siliceous shales, containing narrow interstrata of softer shales. In these the well-known and characteristic pseudomorphs after salt were found. During the formation of the Devonian beach that now remains quartzite and quartzitic shales, portions of the water, that even at so early a geological period contained sodium chloride, were separated from the main body. Upon evaporation the mineral constituents of the water crystallized. Subsequent inundations of the places that had scarcely been laid dry, brought with them sand and silt, covering the newly formed crystals. By the gradual percolation of water through the cover the salt was dissolved, and a quantity of the material composing the cover found its way into the cavities thus produced. It will be noticed, therefore, that whenever these pseudomorphs of sand after salt are found *in positu*, the crystals will be observed on the *lower* side of the stratum containing them. Occurrences of this kind are not infrequent in younger formations both of this country and Europe. Besides these pseudomorphs, scales and fragments of bones are found, belonging to some fish of considerable size. Too little material could be collected to admit of any identification, even only generically. Small scutellae also occur, probably belonging to the same animal. This stratum, as well as the quartzite underlying it, can be traced on the southern side of the granite strip."*

In the summer of 1901 the southern portion of the Needle

*Endlich conceived the granite of this region to be an extreme product of the metamorphism of early Paleozoic sediments, and this view seems to have influenced his statement that at Devon Point the granite "showed a very marked stratification, conformable with that of the superincumbent sedimentary beds." In fact, the granite is unusually coarse-grained, massive, and homogeneous in composition, exhibiting nothing to warrant the repeated references to its origin from sediments.

Mountains quadrangle was mapped geologically by the writer, assisted by Ernest Howe and J. Morgan Clements. Devon Point and the exposures to the southwest were visited, but as the remark of Endlich concerning the fish remains had escaped attention, they were overlooked in the effort to secure fossils from the Ouray limestone. In 1903, however, a special trip was made by the writer and Mr. Albert Johannsen to Devon Point and the adjacent exposures in special search for the fish remains.

The relation of the beds at this locality is shown in the accompanying detailed section.

Section of Paleozoic Formations, Devon Point, Colorado.

TOP.		FEET.
	Ouray limestone remnant, estimated	25
	Elbert formation.	
12.	Red shale or clay. Strong red color, uniform composition; when dry makes soft, crumbling flakes at exposures	5
11.	Sandstone or quartzite. A layer of variable grain, fine or coarse, not persistent, gray, full of fragments of fish scales in some places; free from them in others	± 1
10.	Calcareous shales and thin limestone, buff or gray in color, breaking up readily into slabs or flakes. Salt casts are common in this division. A thin, discontinuous red purplish, sandy layer full of scale fragments occurs locally	25
9.	Thin layers of quartzite, limestone, and red calcareous shale, alternating. Limestone is arenaceous, dull gray, few layers reaching 6 inches in thickness	8
8.	Quartzite, fine-grained, gray, hard, in layers 2 or 3 inches thick	2–½
7.	Red, calcareous shale	1–⅓
6.	Limestone, yellow, earthy	–¾
5.	Calcareous and sandy shales, variegated, yellow, buff, lilac	1–⅓
4.	Quartzite, fine-grained, yellow-brown	1–
3.	Sandy shale, a harder layer in middle. Red, greenish, or mottled	5–
2.	Sandy limestone, shaly in part, rich in fish scales and plates	± 1–
1.	Red shale, calcareous, and sandy, with specks of bone or shell	2–
		54

TOP.		FEET.
	Ignacio formation.	
5.	Quartzite conglomerate with small pebbles, gray or pink, hard and causing a distinct ledge (may belong to Elbert)	3–½
4.	Quartzose sandstone and sandy shale, dark dull red, in layers 6 inches or less in thickness	5
3.	Quartzite, fine-grained, hard, gray, in beds 1 to 5 feet in thickness with thin shale partings. Cross-bedding common	24
2.	Sandstone and quartzite, fine and uneven grain in beds 2 or 3 feet thick, with red, sandy shale layers between	17
1.	Crumbling shaly sandstone, dark, dull red in color, mainly of quartz with some red feldspar grains. A coating of limonite on particles causes color	2–½
		52–
	Base of section is coarse biotite-granite.	

The quartzite formation, measuring 52 feet in thickness at Devon Point, is called the Ignacio quartzite in the Silverton folio (now in press) and it is believed to be of Upper Cambrian age, since the only fossil thus far found in it is a small shell which, according to Mr. Charles D. Walcott, is apparently an *Obolus*, closely related to *O. loperi*, known elsewhere in Colorado. The strata between the quartzites and the Ouray limestone, carrying fish remains at the base and also near the top, seem unquestionably to form a lithologic stratigraphic and faunal unit, and for these strata the name *Elbert formation* is here proposed. The name is derived from Elbert creek, a western tributary of the Animas, entering it just above Rockwood, which flows for several miles on a broad bench between the Animas canyon and the high scarp formed by the Hermosa Upper Carboniferous formation. On this bench the Ignacio, Elbert and Ouray formations are particularly well exhibited. The first name is from the Ignacio lakes, lying on this bench and drained by Elbert creek.

The Elbert formation has been observed below the Ouray limestone in several quadrangles of the San Juan region and many exposures have been studied. While the reader is referred for details to the Needle Mountains, Durango, Engineer Mountain, and Silverton folios, now in press, or soon to be completed, some statements of its characteristics may be made.

Its general lithologic character is fairly well illustrated by the section at Devon Point, although many of them have been noted. The most persistent feature is the crumbling calcareous

shale division, with its casts of salt crystals, by which it may quickly be recognized in nearly all localities. Especially where the formation is found capping a bench or isolated knoll, as at Overlook Point and several other places on the granite surface north from Endlich Mesa, the thin limestone slabs covered with these casts are often very abundant. As was noted by Endlich, the casts were found on the under-surface of layers and testify to peculiar local conditions. While commonly on earthy limestone, the casts have been noted on coarse quartzose sandstone. The most important variation in the lithologic character of the Elbert formation is in the appearance of dense, earthy limestone of conchoidal fracture, in several beds in its upper portion. This development is most notable on the west flank of the Needle Mountains, and also at Bluebird Park, in the northwestern section of the Needle Mountains quadrangle.

The only fossils as yet obtained from the Elbert formation are fish remains, and the most productive locality discovered is that of Devon Point, already described. The remains were found at the base, and also very near the top of the section referred to the Elbert, showing the formation to be a well defined unit as to its fauna. Fish remains have also been discovered at two other localities, to be briefly mentioned.

At about one mile south of Rockwood, and close to the railroad track, a block of pale reddish quartzite was found at the base of the talus slope, upon which were rather indistinct remains of three individual fishes. The ledge of quartzite just above this talus heap belongs to the Ignacio Cambrian quartzite, but the sloping bench between that ledge and the cliff of Ouray limestone some yards farther back is occupied by the Elbert formation. Repeated search has failed to reveal the stratum from which the fish-bearing slab came, and no other remains were obtained. It is almost certain, however, that the slab in question came from a thin bed in the lower part of the Elbert section.

Another, and somewhat different, occurrence of fish remains was found on Little Cascade creek, about one-half mile south of Columbine lake and seven and one-half miles north of Rockwood. At this point the shales containing salt casts are succeeded by several massive limestones alternating with shaly strata. Several thin layers rich in finely comminuted fish scales or plates occur beneath the limestones, and in one of the limestones, resting with irregular contact upon such a layer, a few large plates were found.

All the fish remains above mentioned have been examined by Dr. C. R. Eastman, who, in the accompanying paper, describes the fauna represented by them and discusses their interest from the paleontological standpoint. From the strati-

graphic point of view, the discovery of this distinct ichthyic fauna leads to certain correlations and gives much desired information concerning the lower Paleozoic section of western Colorado.

The most evident correlation of the Elbert formation is with the so-called "Parting Quartzite" of central Colorado, in which Spurr found fish remains determined by Eastman as of Upper Devonian character, and related to certain forms from the Elbert formation.

The name "Parting Quartzite" was used by Emmons in the Leadville monograph* for a quartzite formation 70 feet or less in thickness, occurring below the "Blue Limestone" in which Lower Carboniferous fossils had been found, and the "White Limestone," supposed to be of Silurian age. The "Parting Quartzite" was also provisionally assigned to the Silurian.

At Aspen, on the northeastern flank of the Elk mountains, Spurr† found the beds corresponding in stratigraphic position to the Parting Quartzite of Leadville, to consist of alternating dolomite, dolomitic shale, and quartzite, the last on the whole subordinate, but the old name for the formation was retained. From certain shaly beds at Aspen, Spurr and Tower obtained the fish remains referred to by Dr. Eastman in the accompanying paper. Upon the provisional determinations of this material by Walcott and Girty, the Devonian age of the "Parting Quartzite" was advocated by Spurr. He also pointed out the resemblance of the fish-bearing formation of Aspen to the beds observed by Walcott‡ in the lower Kanab valley of Arizona, briefly stated to contain "placoganoid fishes of a Devonian type."

The stratigraphic equivalence of the Elbert formation of the San Juan region with the "Parting Quartzite" is further supported by the correlation of the Ouray and Leadville (Blue) limestones, rendered necessary by the studies of Girty, who shows that both possess an upper Devonian invertebrate fauna in their lower portions and a Mississippian fauna in their uppermost strata. The Carboniferous forms only were found at Leadville, and the Devonian fauna was the first obtained from the Ouray limestone.

The correlation of the Elbert formation and the "Parting Quartzite" with the strata of the Kanab valley, already suggested by Spurr, is of special interest in view of the relations of the Elbert fishes and the suggestions made by Eastman regarding the geographic connections of that fauna. Unfortu-

* Mon. U. S. Geol. Survey, vol. XII, p. 61.

† "Geology of the Aspen Mining District, Colorado," U. S. Geol. Survey, Mon. XXXI, 1898, pp. 13-22.

‡ This Journal (3), vol. xx, 1880, p. 224.

nately the fossils obtained by Walcott in the Kanab section are not at present available for comparison with the Colorado forms. As Spencer pointed out in discussing the relations of the Ouray limestone,* "it is very probable that the lower part of the Red Wall limestone [Kanab section] is equivalent in age, as well as in position, to the Devonian limestone of Colorado."

While certain correlations for both the Elbert and Ouray formations seem definitely indicated by present knowledge, meagre as it is in some directions, there is a marked contrast between the lower Paleozoic section of western Colorado and that of the Front range, especially as exhibited near Canyon City.

A marked difference also exists between the Kanab section and that of central Nevada, and other localities of the Great Basin. The faunal problem involved is pointed out by Dr. Eastman, and it is clear that the conditions controlling the character of the sedimentary beds form also a most inviting subject for investigation.

* This Journal (4), vol. ix, 1900, p. 133.

Art. XXIX.—*On Upper Devonian Fish Remains from Colorado;** by C. R. Eastman.

Through the courtesy of Drs. Whitman Cross and T. W. Stanton, of the United States Geological Survey, a number of Paleozoic fish remains from Colorado have recently been placed in the hands of the writer for investigation. The greater number of these were collected by Dr. Cross in the San Juan region, while engaged on the survey of the Durango, Engineer Mountain, and Needle Mountains quadrangles. A few detached plates and scales from Aspen, collected some years ago by J. E. Spurr, complete the collection. The character of the remains is indicative of an Upper Devonian horizon for all the localities, and in the case of at least two of them, an Upper Devonian invertebrate fauna has been found in beds overlying the fish-bearing strata. For an interesting account of the stratigraphy of the region, the reader is referred to the preceding paper by Dr. Cross, wherein the name of Elbert formation is proposed for the fish-bearing beds. In the present article it will be sufficient to point out the general nature of the vertebrate fauna, and to inquire into its relations with other Devonian assemblages. The several localities may be considered in the following order.

Durango Quadrangle.

The specimens from the Elbert formation of Rockwood being of exceptional interest, the details of their occurrence may be noted rather fully. They are all from a single slab of quartzite found in the talus at the base of a cliff about one mile south of Rockwood. It is stated by Dr. Cross in memoranda accompanying these specimens that their probable source, as indicated by lithological evidence, is "at least 100 feet above the basal conglomerate, which here rests upon granite. Above the quartzite ledge, with a small covered interval, comes the Ouray limestone, containing a Devonian invertebrate fauna. The variable quartzite series below the limestone in the Animas Valley never exceed 300 feet in thickness, and have yielded no other forms, though carefully searched for a number of miles along the outcrop. . . . The occurrence of fish remains in the Silurian at Canyon City, as described by Walcott, suggests that these fish remains from near Rockwood belong to Silurian beds intermediate between the Cambrian and the Devonian. Very careful search did not suffice to detect the layer from which the slab in question came." In a

* Published by permission of the Director of the United States Geological Survey.

later communication he remarks that "the greater part of the quartzite above the talus heap is supposed to belong to the Cambrian member of the series, and the Elbert formation is known on the little bench just at the head of the talus pile. For some time past I have regarded it as almost certain that the slab came from the Elbert formation."

The recognizable specimens on this slab are three in number, and all belong to a large species of Bothriolepis which cannot be identified with any previously described. Exceed-

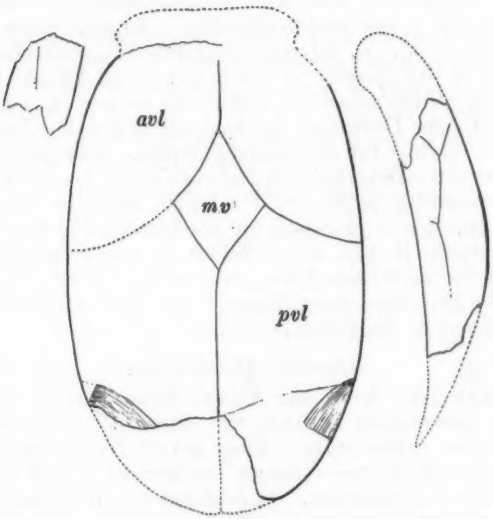

FIG. 1.—*Bothriolepis coloradensis*, sp. nov. × ½.

ing the average of *B. canadensis* in size, it is slightly inferior to *B. major;* but from both of these the new species is distinguished by its different style of superficial ornamentation, general proportions of the body and appendages, and by peculiarities in the outline and structure of the ventral plates. It is difficult to frame a satisfactory diagnosis of the new form, all three individuals presenting only the ventral aspect, and none of them exhibiting the head, though the pectoral members are attached. At the same time it is possible to form a fairly accurate concept of the relations between this and other species, and for sake of comparison with the well known *B. major*, figures are given showing the topography of the ventral surface in each (figs. 1, 2). In *B. canadensis* the rhom-

boidal median ventral is relatively smaller, and the surface ornamentation of all the plates is finer and of different pattern. The appendages, too, are longer, and more tapering distally. *B. major* has the median ventral larger and more exposed than in any known species, its outline being sometimes polygonal or slightly rounded (fig. 3). The remaining species of Both-

FIG. 2.—*Bothriolepis major* (Ag.). × ⅔.

riolepis are excluded from comparison with the new form, which may be known as *B. coloradensis*, by reason of their smaller size, or nature of their superficial ornamentation.

The ornament of *B. coloradensis*, though by no means so well preserved as one might wish in the Rockwood specimens, is clearly of the tuberculate order; here and there the tubercles appear to be more or less confluent, but nowhere do they fuse into vermiculating ridges, as in other American and some foreign species. The center of ossification in the posterior

ventrals is situated near the outer margin some distance behind the middle of the plate; in advance of this point the vascular canals radiate in all directions between parallel with and at right angles to the median line, but behind it they are crowded together and directed obliquely backward. This condition is apparent in all three individuals, and is indicated by the shading in fig. 1.

The ventral armour of the best preserved individual, that shown in the figure, has a width across the middle portion of 8·5^{cm}, and an estimated total length of about 14^{cm}. The largest

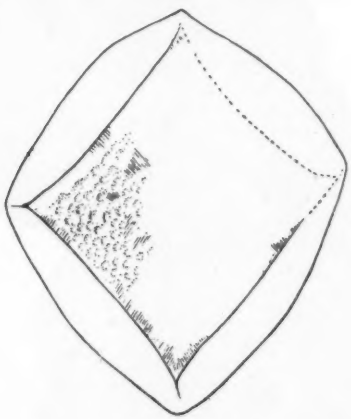

FIG. 3.—*Bothriolepis major* (Ag.). Median ventral, × ½.

example of *B. canadensis* with which the writer is acquainted displays a corresponding width of 10^{cm}, and length of 16^{cm}. *B. major* attains even larger dimensions, the carapace and head, according to Traquair, measuring sometimes 1·5 feet. The length of the pectoral appendages in the new form appear to be intermediate between those of the above-named species, but their covering plates are not sufficiently well preserved to permit of detailed comparisons. In the drawing, the distal end of one of the appendages, which is not serrated, and also a portion of the left posterior ventral have been added from a second specimen, otherwise the parts are shown as they occur in a single individual. The outline of the median and posterior ventrals is perfectly distinct, but the remaining sutures, including those of the pectoral members, are unfortunately obliterated. A very unusual feature in this genus is the obtusely rounded posterior margin of the plastron. On the whole, it appears probable that the relations of the Colorado

species are closer to the European *B. major* than to any other member of the genus.

Needle Mountains Quadrangle.

The principal fossiliferous localities of the Elbert formation, and at the same time historically the most interesting, are those occurring along the eastern edge of the Endlich mesa, *Devon Point* being the name given by Dr. Cross to the most productive. Here the fish remains are distributed throughout beds near the base, and also near the top of the section, being in fact so abundant as almost to justify the name of "fish-bed." And yet the variety of forms represented is surprisingly meagre. Portions of Bothriolepis armour are plentiful, probably not more than two species being represented, however. In addition there occur scales belonging to two species of Holoptychius, but this is all. No Dipnoan remains, and no Arthrodires, which invariably accompany Bothriolepis and Holoptychius in the Upper Devonian, are at present known from this locality. In fig. 4 is shown a weathered fragment of a pectoral limb of Bothriolepis, the external layer having been removed, and the bone substance appearing in longitudinal section. No characters remain for determining the species, yet its large size appears to indicate an identity with *B. coloradensis*. Some of the smaller fragments display an ornament of vermiculating ridges similar in all respects to that observed in *B. leidyi*, from the Catskill of Pennsylvania; and in the absence of more decisive evidence, they may be provisionally referred to that species.

4

The scales of Holoptychius shown in figs. 5 and 6 are preserved in the form of impressions, but the characteristic tubercles and ridges of the exposed surface are clearly indicated. Both of these scales fall within the limits of *H. giganteus*, according to the original definition of that species as given by

Agassiz, allowance having been made by him for variation amongst scales belonging to different parts of the body in the same fish. The species was subsequently divided by Newberry, who included under the name of *H. tuberculatus* those scales in which the tubercles remained distinct, and were not fused into continuous, longitudinal ridges. As for Newberry's *H. americanus*, this resembles Agassiz's species in having the ridges irregularly tortuous, and more or less interrupted and branching, hence it will be seen that the precise determination

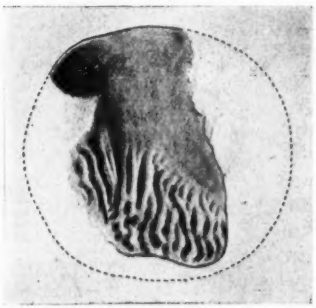

FIG. 5. — *Holoptychius giganteus* Ag. Scale, × ¼.

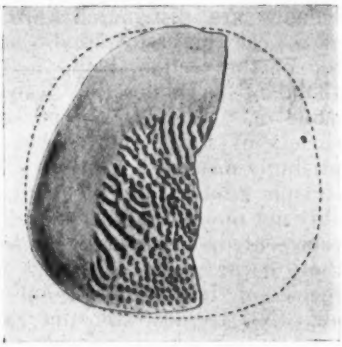

FIG. 6. — *Holoptychius tuberculatus* Newb. Scale, × ¼.

of detached scales is a matter of some difficulty. Probably we shall not err greatly in identifying the original of fig. 5 as *H. giganteus* Ag., and that of fig. 6 as *H. tuberculatus* Newb.

Engineer Mountain Quadrangle.

From Station No. 209, a locality on Little Cascade Creek, one half mile south of Columbine Lake, Engineer Mountain Quadrangle, a single finely tuberculated plate was obtained by Dr. Cross, which appears to be a posterior ventral of some Arthrodire, of about twice the size of the type species of Coccosteus. Occurring as it does in the detached condition, and more or less injured by weathering, even an approximate determination is impossible.

Pitkin County.

The few fragments obtained by Mr. Spurr from the vicinity of Aspen are poorly preserved, and specifically indeterminable.* Two or three finally tuberculated plates are probably to be regarded as of Arthrodire nature, and the presence of

* This remark applies only to the small portion of Mr. Spurr's collection which has as yet come under the writer's observation. At the time this article was written, it was not practicable to obtain access to the remaining

Dipnoans is indicated by certain smooth scales displaying their characteristic perforations. These latter, however, are noteworthy for furnishing the only indication we possess at present of the occurrence of Lung-fishes in the Colorado Devonian.

General Conclusions.

It has already been remarked that the remains brought to light by Dr. Cross are indicative of an Upper Devonian horizon. No other conclusion seems possible in view of the fact that Bothriolepis is an exclusively Upper Devonian genus, and the greater number of Holoptychius species occur in beds of the same age. The two species of the former genus already known from this country, and dozen or so of Holoptychius, are limited to the Chemung and Catskill groups of New York and Pennsylvania. One species of Bothriolepis (*B. canadensis* Whiteaves), and one of Holoptychius, have been described from the Upper Devonian of the Province of Quebec, Canada. These genera are represented abroad by various species found in the Upper Old Red Sandstone of Scotland, and in the Upper Devonian of Belgium and Northwest Russia. The vertebrate fauna of which they form part is composed of Ostracophores, Arthrodires, Dipnoans, Crossopterygians and Elasmobranchs, and it is interesting to note that all of these groups with the exception of the last-named are represented in the Colorado Devonian.

Regarding the origin of the Colorado fauna, little can be said with positiveness. The new species of Bothriolepis appears to be most closely related to *B. major* of Scotland and Russia, and if the fragments showing vermiculated ornamentation are correctly interpreted as belonging to *B. leidyi*, this identification, with that of *Holoptychius giganteus*, place the fauna in relation with the Catskill of Pennsylvania. The Chemung-Catskill of the eastern States betrays an unmistakably European origin, but there is good reason to suppose that a barrier existed between the eastern and western regions during the late Devonian, since neither Holoptychius nor Bothriolepis remains have been found west of New York and Pennsylvania. From this latter region also, the Upper Devonian Ptyctodonts and Dipnoans of Iowa and contiguous States were entirely excluded. Assuming that there was no connection between the eastern and western areas toward the close of the Devo-

specimens, nor to the interesting material collected by Dr. C. D. Walcott from the lower Kanab canyon of Arizona in 1879, owing to the limited storage facilities of the Museum, and absence from Washington of the proper custodians. Mr. Walcott's only publication in regard to the Kanab material is to be found in this Journal [3], vol. xx, p. 224.

The Aspen material is briefly described by Dr. G. H. Girty, in vol. xxxi, p. 20, of U. S. G. S. Monographs (J. E. Spurr: *Geology of the Aspen Mining District*). Without having actually seen the teeth, which are there provisionally referred to "Rhizodus," a Carboniferous genus, we may be permitted to hazard the presumption of their belonging to Holoptychius.

nian, it is difficult to understand how members of the Chemung-Catskill fauna could have reached Colorado, unless they came by some southern route as yet unknown. On the other hand, a Eurasiatic origin by way of Behring Straits cannot be regarded as an impossibility, nor even as an improbability, since the invertebrate fauna of the superjacent formation has been shown by Dr. Girty* to be "not closely similar to the faunas of the eastern and central United States," but exhibits, in his opinion, "a closer parallel with the Devonian of the Ural Mountains."

Attention should also be called to Professor Calvin's observations on the Devonian system of Iowa, which go to show that the eastern and western areas were geologically isolated. According to this author,† "the eastern Devonian faunas probably migrated from the northeast along the eastern border of the continental nucleus, while the western faunas of the same period seem to have come from the northwest along the western border of the Devonian continent." He also points out that the Iowa Devonian fauna is related in some respects to that occurring at the Ramparts of the Mackenzie River, and the present writer has commented on certain resemblances between its vertebrate constituents and the corresponding fauna of Russia.

For the present, the question as to the origin of the vertebrate fauna of the Colorado Devonian must be considered as problematical, and one which will require considerable further evidence and investigation before it can be answered satisfactorily. It is evident that the remains thus far obtained by Dr. Cross constitute not only an important paleontological discovery, but open up problems of distribution, and others of a geological nature, which are worthy of careful study.

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EXPLANATIONS OF FIGURES.

FIGURE 1.—*Bothriolepis coloradensis* sp. nov. Elbert formation; Rockwood, Col. Ventral armour, ½ natural size. *avl*, Antero-ventro-lateral; *mo*, Median ventral; *pvl*, Postero-ventro-lateral plates. (U. S. Nat. Mus.)

FIGURE 2.—*Bothriolepis major* (Ag.). Upper Old Red Sandstone; Elgin, Scotland. Ventral armour, seen from the visceral aspect, × ⅝. (Original in Mus. Comp. Zoöl. at Cambridge.)

FIGURE 3.—*Bothriolepis major* (Ag.). Median ventral, × ½. *Ibid.*

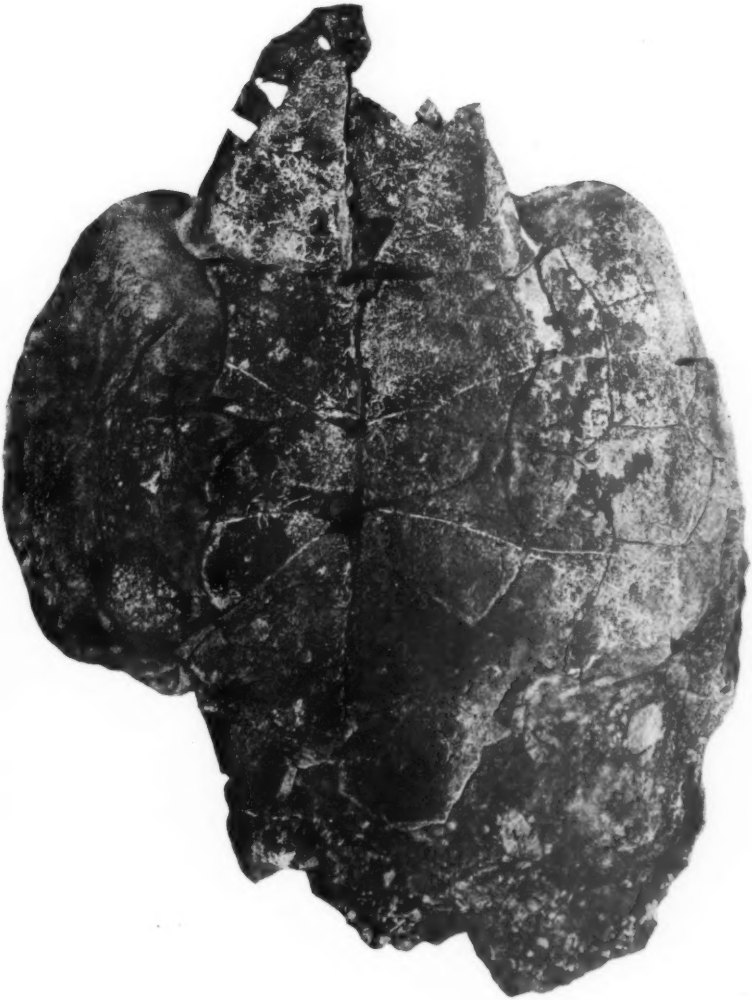
FIGURE 4.—*Bothriolepis coloradensis* (?) sp. nov. Fragmentary pectoral appendage, × ½. Elbert formation; Devon Point, Colorado.

FIGURE 5.—*Holoptychius giganteus* Ag. × ½. Same locality.

FIGURE 6.—*Holoptychius tuberculatus* Newb. × ½. Same locality.

* The Carboniferous Formations and Faunas of Colorado (Profess. Paper U. S. Geol. Surv., No. 16, p. 162), 1903.

† Ann. Rept. Iowa Geol. Surv., vol. VIII (1897), p. 221. One may compare also the following important papers on Devonian paleontology: Schuchert, C., On the Faunal Provinces of the Middle Devonic of America, etc. (Amer. Geol., vol. xxxii, pp. 137–162), 1903. Williams, H. S., The Correlation of Geological Faunas (Bull. U. S. Geol. Surv., No. 210), 1903.



BAËNA MARSHI Hay.

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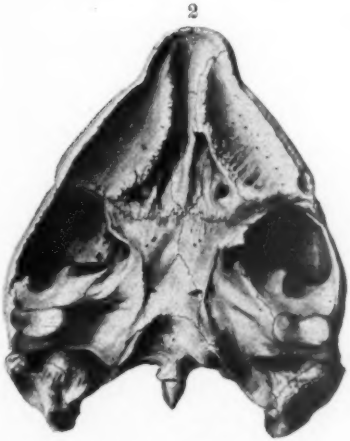

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BAËNA CEPHALICA Hay.

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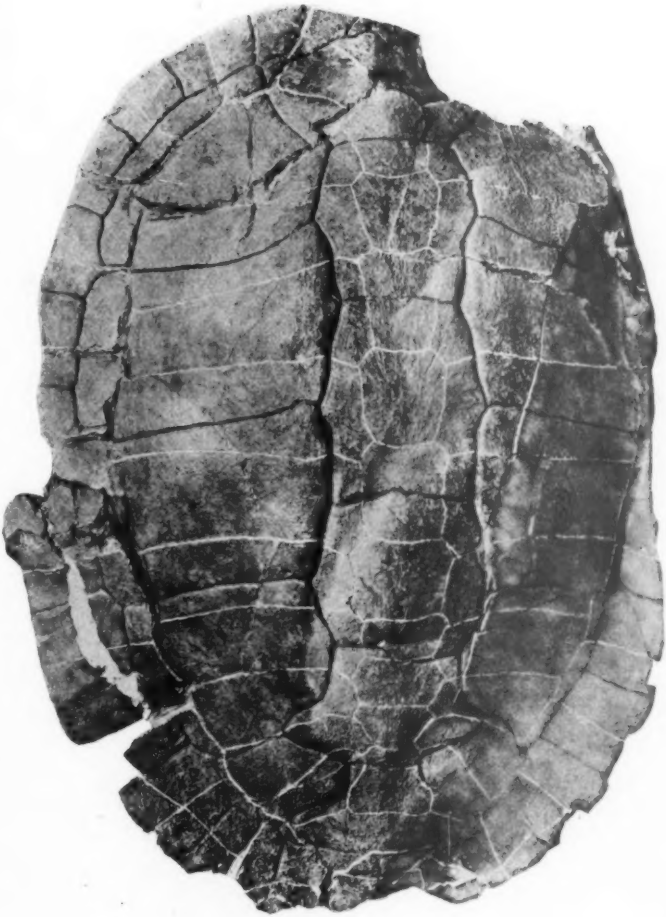
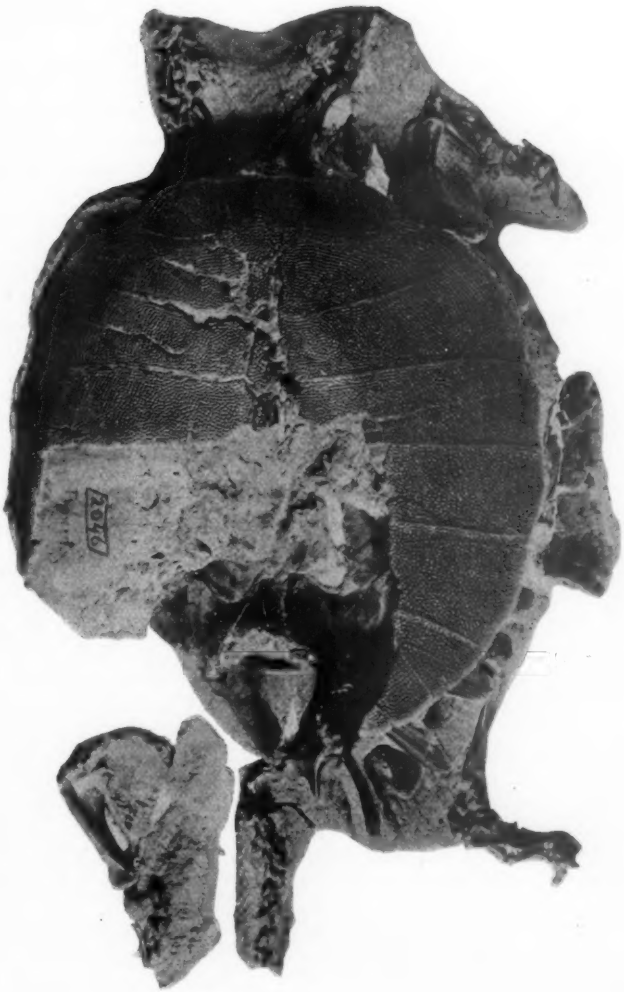
BAPTEMYS WYOMINGENSIS Leidy.



CHRYSEMYS WYOMINGENSIS (Leidy).

HADRIANUS MAJUSCULUS Hay.



ASPIDERETES BEECHERI Hay.

ART. XXX.—*On some Fossil Turtles belonging to the Marsh Collection in Yale University Museum;* by O. P. HAY. (With Plates XI–XVI.)

THE present paper is the result of a study of some of the extinct turtles in the collections of vertebrate fossils brought together by Professor O. C. Marsh. The privilege of making the investigation was first granted by the late Professor Charles E. Beecher; after his death it was renewed by the acting curator of the collection, Professor L. V. Pirsson. For assistance and courtesy the writer's thanks are due to all the officers having connection with the department of vertebrate paleontology in Yale University. The negatives from which several of the plates have been prepared were furnished by Dr. George R. Wieland. The wash drawings were made by Mr. Erwin Christman, of the American Museum of Natural History.

Further remarks on the species here treated and additional illustrations will, it is hoped, be presented in the writer's forthcoming monograph of the fossil turtles of North America.

Baëna marshi sp. nov.

Plate XI; Text-figure 1.

The type of this species was collected in 1889, by Professor J. B. Hatcher, in the Laramie deposits of Converse County, Wyoming, between Buck and Lance creeks.

The specimen has suffered considerable damage. There are present the central region of the carapace and most of the left side, the greater portion of the plastron, and the matrix forming a cast of the interior of the shell. The length of the shell can be determined only approximately. It must have been at least 300^{mm}, with a breadth of 220^{mm}.

On account of the obliteration of the sutures of the carapace, its structure cannot be made out. The bones along the median region have a thickness of from 10 to 13^{mm}. The outer surface is smooth. The sulci between the various dermal scutes are narrow and shallow, and in many places cannot be traced. The second, third, and fourth vertebral scutes varied in width from 64 to 70^{mm}.

The posterior extremity of the plastron is missing; hence the length of the plastron cannot be accurately determined, nor the form of the posterior margin. The total length, however, must have been close to 260^{mm}. The following table presents the most important dimensions. In order that the distinctness of the species from *B. hatcheri*, which is from the same deposits and locality, may be appreciated, the dimensions of the plastron of the latter are also given.

Dimensions.	*Baëna marshi.*	*Baëna hatcheri.*
Length of plastron	260±	305
Width of bridge	120	115
Length of anterior lobe	70	106
Width of anterior lobe	95	115
Length of posterior lobe	65±	98
Width of posterior lobe	90	120

1

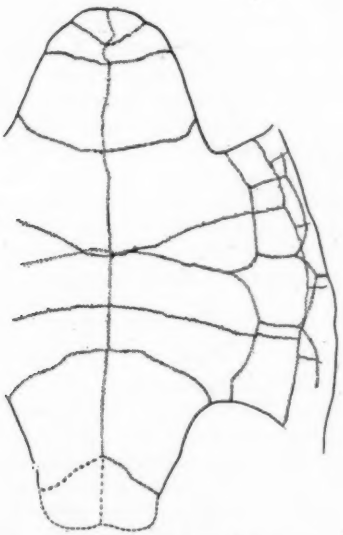


FIGURE 1.—*Baëna marshi.* Diagram of plastron.

It will be observed that, while the plastron of *B. hatcheri* is considerably longer, the bridge is slightly shorter. Further, the lengths of the anterior and posterior lobes of *B. marshi* are much less in proportion to the total length of the plastron than they are in *B. hatcheri.*

The central region of the plastron is concave. This may indicate that the individual was a male. The mesoplastra are large, wedge-shaped bones. They meet along the midline for a distance of 23^{mm}, and their outer ends are 65^{mm} wide.

The following are the antero-posterior widths of the various plastral scutes: Intergulars, 17^{mm}; gulars, 10^{mm}; humerals, 46^{mm}; pectorals, 50^{mm}; abdominals, 47^{mm}; femorals, 53^{mm}; anals, about 45^{mm}. On the bridges there are four inframarginals, of which the inguinal is the largest, and the axillary somewhat the smallest.

This species differs from *B. hatcheri* in the greater thickness of the bones of the carapace and in the shorter lobes of the plastron. It is named in honor of the late Professor Othniel C. Marsh.

Baëna cephalica sp. nov.

Plate XII, Figures 1–3.

The name *Baëna cephalica* is given to a fine skull which belongs to the Yale University Museum, and which was collected in the Laramie deposits of Converse County, Wyoming, by Professor J. B. Hatcher. The specimen bears Professor Marsh's receipt number 2110.

In general form the skull is broad behind, and flat above, with pointed snout. The length from the snout to the occipital condyle is 67^{mm}; to the end of the supraoccipital spine, 74^{mm}. The greatest breadth, just in front of the tympanic chambers, is 65^{mm}. From these chambers the width diminishes to the snout. There is first a convexity in the outline, which terminates at the hinder end of the maxilla; a second and longer one which ends behind the premaxilla, and a third one which ends at the premaxillary symphysis. The flat upper surface of the skull descends each way to the perpendicular sides. The sides of the face about the orbits look upward and outward, as well as forward. The tympanic opening is nearly circular, 19^{mm} in perpendicular and 15^{mm} in horizontal axis. The orbit is circular and small, its diameter being 14^{mm}. The nasal opening, as seen from in front, is somewhat heart-shaped, and is directed upward and forward. From the orbit to the tympanic opening is 24^{mm}; from the nares to the orbit is 10^{mm}.

The temporal region is roofed over, not so extensively as in some undescribed Bridger skulls of the same genus. On each side of the supraoccipital, this roof is excavated as far as a line joining the anterior borders of the tympanic chambers. The hinder end of the postfrontal is interposed between the parietal and the squamosal.

In general, the sutures of this skull are very distinct, but no trace has been found of those between the frontals and the parietals. There are distinct nasals. The prefrontal of each side joins the postfrontal, so that the area of the frontals is excluded from the orbit. The postfrontal is large, having a length of 32^{mm}. The jugal is small, having a length of only 8^{mm} and a height of 15^{mm}. The squamosal forms the hinder border of the tympanic opening. Superiorly it has a thin crest, a relic of the former backward extension of the temporal roof. There is a prolongation of the tympanic chamber into this bone. The lower border of the zygomatic bar is considerably exca-

vated. Seen from the side, the maxilla is convex on its lower border. The premaxillæ are distinct from each other and from the maxillæ. At the symphysis they are only 3^{mm} high, but at their union with the maxillæ, 10^{mm} high. As in the Bridger species, there are distinct lachrymal bones. They occupy the position of the descending portion of the prefrontals of other turtles, coming in contact with the vomer.

As seen from below, the maxilla has a broad masticatory surface, its width from the inner border to the cutting edge being 14^{mm}. The inner border of this surface is furnished by the palatine bone. The latter forms the whole of the outer border of the choana. The masticatory surface does not extend forward on the premaxilla. In front of the choanæ there is a deep groove, which anteriorly expands on the lower surface of the premaxillæ. Postpalatine foramina are present.

The pterygoids come in short contact with the maxillæ. They have distinct ectopterygoid processes. Where the posterior part of the palate is constricted, it is 18^{mm} wide. The pterygoids extend backward to the posterior border of the pedicel of the quadrates, thus separating the latter widely from the basioccipital and basisphenoid. There is a considerable groove on each side between the quadrate and the median bones of the base of the skull. The pterygoids join at the midline for some distance in front of the basisphenoid. On each side of the latter, about the middle of its length, is a foramen.

The pedicels of the quadrates are short. The surface for articulation with the lower jaw is deeply concave from side to side; nearly plane from front to back.

The quadrate bone is notched behind for the passage of the stapedial rod.

There appears to have been a system of epidermal scutes covering the upper surface of the skull. Not all the areas occupied by these can be made out with certainty; but some of them are quite distinct. A pair of these seems to have occupied the space between the orbits. Behind each of these is a smaller one which lies over the hinder border of the orbit. A very large scute, or more probably a pair of them, covers the area of the frontal bones and overlaps on the parietals. The posterior half of this scute or scutes is separated by two scutes occupying the midline. One of these, the anterior, is small and circular; the other is elongated and extends backward on the supraoccipital processes of the parietals. It is, of course, possible that the latter scute was divided along the midline.

The study of this skull confirms the view of Dr. George Baur, drawn from the skull of *Compsemys plicatula*, that there are in the skulls of the Amphichelydia few pleurodiran characters. Nasals are indeed present, but they can hardly be

regarded as distinctive, since there are Cryptodira (Porthochelys) which possess nasals. A short supraoccipital spine is very general among the Pleurodira. The character which especially separates the latter group from the Cryptodira is found in the very broad pterygoids, the posterior ends of which do not separate the quadrates from the basioccipitals. In Baëna, as shown in the present skull and in others from the Bridger beds not yet described, the pterygoids are disposed in the same way as in the Cryptodira.

It appears, in fact, that a considerable number of characters exist in the skulls of Baëna, which belong also to the Athecæ. These are found in the short supraoccipital spine, the large postfrontals, the exclusion of the frontals from the orbits, and the participation of the basioccipital in the formation of the foramen magnum.

The nasals, the lachrymals, and the extensive temporal roof may be regarded as primitive characters.

In Baëna, undoubted pleurodiran characters are seen in the presence of a mesoplastron and in the structure of the cervical vertebræ. The suborder Amphichelydia must thus be regarded as securely founded.

Baptemys wyomingensis Leidy.

Plate XIII, Figures 1–3; Text-figure 2.

Baptemys wyomingensis, Leidy, J., Proc. Acad. Nat. Sci. Phila., 1870, p. 5; Contr. Ext. Fauna West. Terrs., 1873, p. 157, pl. xii, pl. xv, fig. 6.

This species is represented in the Marsh collection by a specimen which was collected in the year 1870, in the Bridger beds, near Millersville, Wyoming. The carapace is almost entire, but somewhat crushed and distorted. The plastron is intact. The nearly complete skull is present; likewise, some of the limb bones. The specimen bears the number 484. It is most valuable on account of furnishing the hitherto unknown skull and the not well-known anterior lobe of the plastron.

When this example is compared with the type some differences are observed, but these are not regarded as of specific value. The most important of these differences is the presence of four, instead of three, inframarginal scutes on each of the bridges.

The only portion missing from the skull is the roof of the orbits and the nasal cavity. This deficiency is fortunately supplied by a skull collected during the year 1903 by the American Museum expedition into the Bridger beds near Fort Bridger.

The skull is wedge-shaped, being broad behind and pointed in front. The length from the snout to the occipital condyle is 67^{mm}; to the end of the supraoccipital spine, 88^{mm}. The

width at the upper border of the tympanic cavity is 58mm. There is no roof over the temporal region, and there is no parieto-squamosal arch. The postorbital arch is but little more than 7mm wide. The zygomatic bar is excavated on its lower border. The interorbital space, as shown by the American Museum specimen, is 23mm wide. The orbits are large, having an antero-posterior diameter of about 20mm. The nares, as shown by the specimen last mentioned, have a perpendicular diameter of 16mm. The upper jaw is convex along its cutting edge, rising in front so as to form a median notch. This edge is sharp throughout its length. In the Yale specimen, the lower jaw conceals a portion of the palate near the cutting edge, but this region is exhibited in the American Museum specimen. Running parallel with the posterior half of the cutting edge, and separated from it by a deep furrow, is a sharp dentated ridge, which has a length of 12mm. When the jaws are closed this ridge fits into a groove in the lower jaw.

The choanæ are far forward. The roof of the mouth is vaulted, not greatly unlike that of Testudo. The vomer appears to have extended backward nearly to the pterygoids. The distance across the palatines at their posterior ends is 20mm. The distance across the constricted portion of the pterygoids is 13mm. There are small postpalatine foramina. The outer border of the palatine bone has not been traced with certainty. In the specimen in the American Museum there appears to be a suture running along the bottom of the groove on the outside of the dentated ridge mentioned above. If this is really the case, this ridge lies on the palatine bone.

The tympanic cavity has its posterior wall open, forming a channel for the passage of the stapedial rod. The sutures between the bones of the skull are closed, and some of them can be traced only with difficulty. There appear to have been no nasals. As shown by the American Museum specimen, the frontals are shut out from the borders of the orbits.

The lower jaw appears to have formed a slight beak in front. The anterior half of the efficient border forms a cutting edge which shears against that of the maxilla. Posteriorly the edge divides so as to produce two ridges which enclose between them a deep groove about 4mm wide. It is this groove which receives the dentated ridge of the palate.

Portions of the hyoid apparatus remain clinging to the base of the skull. This apparatus resembles closely the same organ in *Chrysemys elegans*, and is much unlike that of *Dermatemys*.

Text-figure 2 shows the form of the plastron, and this agrees with that of the specimen in the American Museum. Leidy (Contr. Ext. Fauna West. Terrs., pl. xv, fig. 6) has figured the anterior end of a plastron which is truncated and slightly exca-

vated. This may be an individual variation, or it may indicate a distinct species. In all the known specimens of this species the intergular and gular scutes are absent, and the humerals extend forward to the front of the plastron.

A comparison of the skull of this species with that of *Dermatemys mawii*, as described and figured by Bienz (Rev. suisse de Zool., iii, 1895, p. 61, pl. ii, figs. 1–5) shows that the two are similar in general form and in the absence of a temporal roof. The structure of the upper and lower jaws is quite dif-

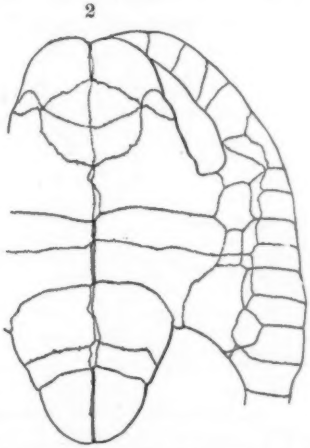


FIGURE 2.—*Baptemys wyomingensis.* Diagram of plastron.

ferent in the two genera. In Dermatemys the choanæ are underfloored by the palatal plates of the maxillæ and are pushed well backward. In Baptemys they are far forward in the vaulted palate.

Chrysemys wyomingensis Leidy.

Plate XIV ; Text-figures 3, 4.

Emys wyomingensis Leidy, J., Proc. Acad. Nat. Sci. Phila., 1869, p. 66; Contr. Ext. Fauna West. Terrs., 1873, pp. 140, 340, pl. ix, figs. 4, 5, pl. x, figs. 1, 2. Hay, O. P., Bibliog. and Cat. Foss. Vert. N. A., 1902, p. 448.

In the collection of fossil vertebrates made by Professor Marsh in the year 1874, there is an unusually interesting specimen of turtle. This is a nearly complete shell, and was obtained in the Bridger beds at Millersville, a point a few miles east of Fort Bridger, Wyoming. It is referred without doubt to the species above named. It is interesting from the fact that it possesses a number of supernumerary structures. That is, it has nine neurals, instead of eight; ten pairs of costal

plates, instead of eight pairs; twelve pairs of peripheral bones, instead of eleven pairs; six vertebral scutes, instead of five; five pairs of costal scutes, instead of four pairs; and twelve pairs of marginal scutes, instead of eleven pairs. There is no doubt regarding the presence of any of these extra bones and scutes, since all the sutures and sulci are very distinct.

A comparison of this carapace with Leidy's figure of *Emys wyomingensis* shows that the whole anterior portion agrees with that figure, only such deviations as might be expected in two individuals of the same species being present. The posterior third, however, leads one into difficulties.

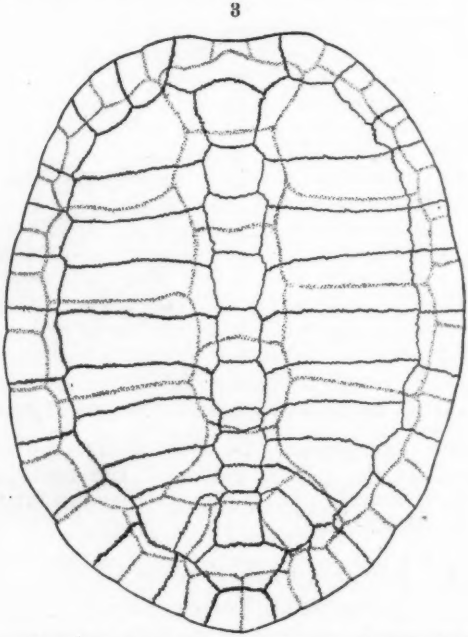


FIGURE 3.—*Chrysemys wyomingensis.* Diagram of carapace of individual possessing supernumerary structures.

The normal number of costal plates is, of course, eight pairs. In some of the living species of North American Trionychidæ the costals are reduced to seven pairs. Dr. Boulenger has stated that in some fossil marine turtles there are nine or ten pairs of costals, but he has not mentioned the species. Such cases may occur, but it is doubtful that they are normal forms. Mr. L. M. Lambe (Contr. Canad. Palaeont., iii, 1902, p. 42, fig. 7) has described as a new genus and species *Neurankylus*

eximius, which has nine pairs of costal plates. Dr. George Baur referred to a specimen of *Malacoclemmys geographica* having nine costals. Dr. Boulenger, in his Catalogue, p. 187, states that in a specimen of Pelomedusa he found nine pairs of costal plates; in another, nine plates on one side and eight on the other. Is it possible, therefore, to determine which costal and peripheral bones, and which vertebral, costal, and marginal scutes, in the specimen at hand, are the intercalated ones?

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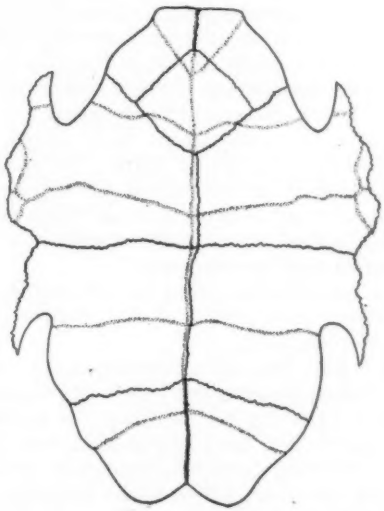

FIGURE 4.—*Chrysemys wyomingensis*. Diagram of plastron of same individual as that of figure 3.

It seems to the writer that there can be no question that the six anterior neural bones and the six anterior pairs of costals, together with the peripherals in contact with the latter, correspond exactly with the six anterior neurals, the six anterior pairs of costals, and the contiguous peripherals, of the type specimen of *Chrysemys wyomingensis*, or, indeed, of any other member of the Emydidæ. It appears to be quite as certain that the seventh pair of costals corresponds with the seventh pair in other emyds. Each is crossed at its upper end by a portion of the longitudinal sulcus, and is in contact with a neural, probably the seventh, and with that behind it.

If, now, one begins at the posterior margin of the shell and works forward, certain conditions may be established. As usual, a pygal peripheral is present. In front of this comes a

broad hexagonal suprapygal, the homologue of which is partly shown in Leidy's figure of the type, and is fully shown by a specimen in the American Museum of Natural History. In all three examples mentioned, this suprapygal is crossed near its anterior end by a sulcus bounding the supracaudal scute in front. In Leidy's type, in front of this suprapygal is another which widens backward. A similar bone is found in the American Museum specimen and in the one here described; but, in both of the latter, the bone is somewhat longer, and is crossed by a transverse sulcus. In Leidy's type, the sulcus crosses on the neural immediately in front,—the eighth.

The last pair of costals in the Yale specimen has all the characteristics of the eighth pair in Leidy's type and in the American Museum specimen. They come in contact with the two suprapygals, are crossed at their anterior ends by a transverse sulcus, and are occupied in their length by the lateral sulci of the hindermost vertebral scute. In the specimen here described these costals do not indeed come in contact with the hindermost neural; but it is no unusual thing for the last pair of costals to be pushed out of contact with this neural, or the real eighth neural may be suppressed.

It is concluded, therefore, that the intercalated costal plates of the present specimen are the eighth and the ninth from the front of the carapace.

Since there is only one extra neural present, it appears to be impossible to determine whether this is the eighth or the ninth from the front. It may be, however, as already suggested, that the true eighth has been suppressed, and that the eighth and the ninth, counting from the front, are both intercalated.

It is likewise uncertain which is the intercalated peripheral, the tenth or the eleventh of this specimen; but it is more likely the tenth, since it is in contact with both the intercalated costals.

As to the vertebral scutes, the first, second, and sixth seem clearly to correspond with the first, second, and fifth, respectively, of a normal emyd. It appears to be quite as certain that the anterior portion of the fourth corresponds with the same portion of the fourth of any other emyd; and again that the posterior portion of the fifth is homologous with the posterior portion of the fourth vertebral of ordinary turtles. Does not this evidence lead to the conclusion that no new scute has been intercalated, but, rather, that the area occupied by the fourth scute in a normal turtle, having been greatly enlarged, has become divided by a transverse sulcus? In the same way the extra costal scute on each side, as well as the extra marginal, may be explained.

The region immediately in front of the most anterior suprapygal presents various evidences of having suffered disturbance.

Notwithstanding the possession of ten pairs of costal plates, this specimen is not elongated, as one might expect it to be. Indeed, the width is relatively greater than in the specimen in the American Museum.

The plastron appears in no way different from that of the other known specimens of the species. It is quite complete, and a pen drawing showing its structure is here presented.

The total length of the carapace is 325^{mm}; the width is 240^{mm}. Leidy's specimen was at least 330^{mm} long and close to 235^{mm} wide.

Hadrianus majusculus sp. nov.

Plate XV; Text-figure 5.

The shell on which the present species is based was received at the Yale University Museum late in the year 1876. It bears Professor Marsh's receipt number 927. The label has

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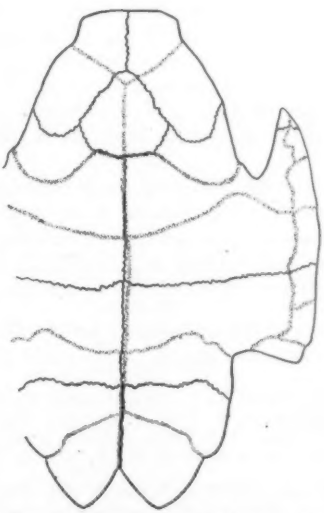

FIGURE 5.—*Hadrianus majusculus.* Diagram of carapace.

the following record: "Turtle from foot of bluff, west side of Murderer's Gap. Nov. 19, 1876. D. Baldwin." Another label states that the specimen came from the "Eocene Bad Lands, Gallina, New Mexico." This locality appears to be in Rio Arriba County, New Mexico. The deposits doubtless belong to the Wasatch epoch.

The upper portion of the shell and one side of it are somewhat damaged. The length of the carapace is 530^{mm}; the greatest breadth was at least 440^{mm}. In form the shell was rather high and vaulted. Over the limbs the peripheral bones are considerably flared upward. The posterior border is rounded and scalloped. The free borders of all the peripherals have acute edges. The form and dimensions of many of the neurals cannot be determined. There appear to have been three suprapygals, the penultimate of which is bifurcate, as in the species of Testudo. The anterior four or five costal plates are alternately narrow and wide, but the proximal and the distal ends of each are of about the same width, thus differing from the costals of Testudo.

The peripheral bones, conspicuously those over the bridges, are much higher than those in the Bridger species, *H. corsoni*. They rise about 90^{mm} above the slight carina which joins the third with the seventh peripheral. The sulci which bound the epidermal scutes are narrow and shallow, but they run in rather deep grooves in the bones. There are two very distinct supracaudal scutes, a right and a left.

The plastron has about the same length as the carapace. There is a distinct lip in front. The rear of the plastron is deeply notched. The antero-posterior extent of the pectoral scutes is considerably greater than in *H. corsoni*.

The large peripherals and the broad pectoral scutes especially distinguish this species from those of Hadrianus hitherto described.

Professor Cope has referred some remains of this genus from the Wasatch of New Mexico to *H. corsoni*, but his specimens were too fragmentary for accurate determination.

Hadrianus majusculus is interesting because of its being the oldest known member of the Chersites, or Testudinidæ.

Testudo brontops Marsh.

Text-figures 6, 7.

Testudo brontops Marsh, O. C., this Journal (3), xl, 1890, p. 179, pl. viii; Vert. Foss. Denver Basin, in Mon. U. S. Geol. Surv., xxvii, 1897, pp. 523, 527, figs. 95, 96. Dana, J. D., Manual Geol., 1896, p. 901, fig. 1516. Hay, O. P., Bibliog. and Cat. Foss. Vert. N. A., 1902, p. 451.

This species has already been briefly described by Professor O. C. Marsh, as cited. The writer has been enabled to study with some care this fine specimen, and here presents diagrammatic figures illustrating the structure of the carapace and the plastron. The structure has been somewhat obscured by crushing, especially along the midline of the carapace.

The length of the carapace is 711^{mm}; the greatest breadth is 651^{mm}. The carapace is truncated in front and broadly

rounded behind. Over the limbs the peripheral bones are considerably flared upward. The sutures separating the nuchal from the first peripherals cannot be traced with certainty. The greatest width of the bone is 175^{mm}; and the length along the midline, 150^{mm}. The first neural bone is oval; the second and fourth, octagonal; the third, hexagonal. The fifth was probably hexagonal, but it is somewhat crushed. The sixth, seventh, and eighth are approximately hexagonal. The anterior suprapygal is bifurcate. The costals of the second, third, fourth,

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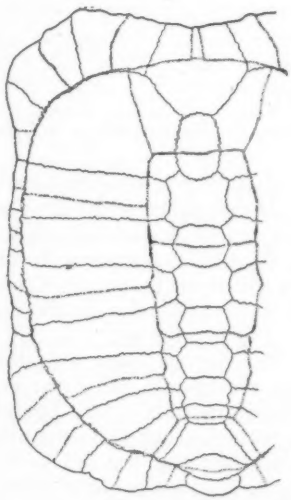

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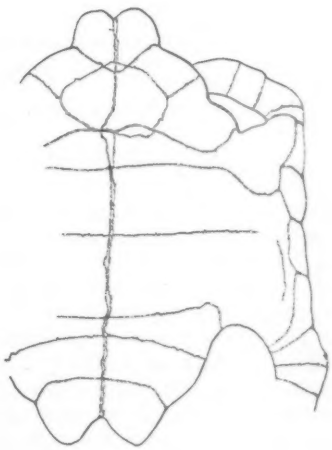


FIGURE 6.—*Testudo brontops.* Diagram of carapace.
FIGURE 7.—*Testudo brontops.* Diagram of plastron.

fifth, and sixth pairs are alternately narrow and wide at their proximal ends, and alternately wide and narrow at their distal ends. The following table gives the dimensions of the costals, excluding the first:

Costal.	Width at proximal end.	Width at distal end.
2	56	106
3	100	73
4	56	90
5	94	56
6	61	95
7	40	75
8	43	62

The second and third vertebral scutes had a width of about 190^{mm}. The sulci of the region of the bridge ran in deep valleys, thus giving a scalloped appearance to the border.

The plastron is quite concave. The lip of the anterior lobe projected boldly beyond the general border of the plastron and beyond the front of the carapace. There is a considerable notch in the posterior end of the plastron. The pectoral scutes are about 55^{mm} wide at the midline; the abdominals, 240^{mm}.

This large and fine species was found in the Titanotherium beds of Indian Creek, Pennington County, South Dakota. It is especially interesting because of its being the oldest known species of the genus. Although so old, it appears to have been as highly differentiated in all respects as are the modern forms of the genus.

Aspideretes beecheri sp. nov.

Plate XVI.

Trionyx foveatus Baur, G., Proc. Acad. Nat. Sci. Phila., 1891, p. 418 (not Leidy).

In the Marsh collection there is a fine specimen of a Trionychid to which the above name is given. It was collected in the year 1889 by Professor J. B. Hatcher and Dr. C. E. Beecher, in the Laramie beds of Converse County, Wyoming, on the east side of Lance Creek. The specific name is given in honor of one of the collectors, Dr. Beecher, whose untimely death has wrought such injury to the science of paleontology.

This specimen was examined by Dr. George Baur and identified by him as Leidy's *Trionyx foveatus*. The present writer does not agree with this determination. Dr. Leidy's species was based on rather scant material, but the ornamentation of the costal bones is characteristic and has led to the identification of the species by Mr. L. M. Lambe (Geol. Surv. Canada, Summ. Rept., 1901, p. 81, pls. i, ii; Contr. Canad. Palaeont., iii, 1902, p. 33, pl. i, figs. 1, 2) in finely preserved and quite complete remains. The latter indicate a Trionychid quite different from the one here described.

The type of *A. beecheri* presents the limbs nearly complete, a portion of the neck, the tail, the shoulder girdle, a large portion of the carapace, and the whole of the plastron.

The carapace had a length close to 325^{mm} and a width of 310^{mm}. At each end of the nuchal, the border has been somewhat excavated. The lateral margins are slightly sinuous, and the posterior border has probably been slightly concave.

The outer ends of the nuchal appear to have overlapped the first costal. The nuchal has its whole upper surface covered with a sculpture like that of the costals. There is a preneural bone, whose anterior border has occupied a notch in the hinder border of the nuchal. The author has elsewhere proposed the name Aspideretes for the Trionychidæ possessing a pre-

neural, the type of the proposed genus being *Trionyx gangeticus* Cuvier. The first neural of *A. beecheri* is hexagonal, with the narrow end directed forward. There is present a second neural of similar form and a portion of a third. The remaining neurals are missing. In all probability there were eight pairs of costal plates, but the eighth is represented in this specimen by the free portion only of the corresponding rib.

The sculpture of the carapace consists of a network of ridges enclosing rather deep pits. Usually these pits are without definite arrangement, but on the distal ends of the costals they arrange themselves in rows parallel with the free borders of the carapace. The walls surrounding the pits rise abruptly from the bottoms of the latter; whereas, in *A. foveatus*, the walls slope upward gradually from the centers of the pits. Furthermore, in the latter species, the pits on the proximal ends of the costals are likely to have quite wide flat spaces between them.

The plastron is complete. The entoplastron is truncated in front, with a slight notch at the midline. The branches include between them less than a right angle. The epiplastra are broad at their anterior ends. They resemble greatly the same bones in *Aspidonectes muticus*. The hyoplastra are not coössified with the hypoplastra. Between the inner ends of the hyoplastra is a large fontanelle which is bounded in front by the entoplastron. Between the inner ends of the hypoplastra is another fontanelle which extends backward to the xiphiplastra. There is no fontanelle between the latter bones. The bridge, where narrowest, has a width of 64^{mm}.

The whole lower surface of the hyoplastra, the hypoplastra, and the xiphiplastra, is covered with a sculpture like that of the carapace, except that it is finer.

The cervical vertebra seen in Plate XVI is probably the fifth. Its length is about 60^{mm}. Seven caudal vertebræ are preserved, forming a series 122^{mm} long; but there were others which have been destroyed. They are very similar to those of *Aspidonectes spiniferus*. The shoulder girdle, the fore limbs, the pelvis, and the hind limbs present no important differences when compared with those of modern Trionychidæ.

It appears probable that this individual was a female of mature age.

The U. S. National Museum possesses a Trionychid which was collected by one of Professor Marsh's parties, while he was vertebrate paleontologist to the U. S. Geological Survey. It was obtained in Converse County, Wyoming, and is referred to *A. beecheri*. It shows the carapace to have been high and convex; also, that it had a preneural, six neurals, and eight pairs of costal plates.

EXPLANATION OF PLATES.

Plate XI.

Baëna marshi Hay; view of the plastron. $\times \frac{1}{3}$.

On the left side of the figure is seen a portion of the matrix which filled the shell and from which the bone has been removed. On the opposite side, posteriorly, is seen some matrix filling the inguinal notch. From photograph.

Plate XII.

Baëna cephalica Hay.

Figure 1.—Skull seen from above. $\times \frac{2}{3}$.
Figure 2.—Skull seen from below. $\times \frac{2}{3}$.
Figure 3.—Skull seen from left side. $\times \frac{2}{3}$.

Plate XIII.

Baptemys wyomingensis Leidy.

Figure 1.—Skull seen from above. $\times \frac{2}{3}$.
Figure 2.—Skull seen from below. $\times \frac{2}{3}$.
Figure 3.—Skull seen from left side. $\times \frac{2}{3}$.

Plate XIV.

Chrysemys wyomingensis (Leidy); carapace, showing supernumerary bones and scutes. $\times \frac{2}{5}$. From photograph.

Plate XV.

Hadrianus majusculus Hay; shell seen from the left side. $\times \frac{1}{4}$. From photograph.

Plate XVI.

Aspideretes beecheri Hay; skeleton seen from above. $\times \frac{1}{4}$. From photograph.

Art. XXXI.—*Air Radiation;* by C. C. Hutchins and J. C. Pearson.

In 1892, one of the present writers carried out, at the request of Professor Cleveland Abbe, some experiments for finding the radiation constant of atmospheric air. The radiation was measured from a hot moving column of air of one centimeter depth in the line of sight, and as close as possible, consistent with proper screening, to the heat-recording apparatus. Owing doubtless to defective surroundings, the results obtained from day to day showed considerable variation; in fact, more than could be produced artificially by changing the normal constituents of air in a closed room, such as dust and moisture, between wide limits. An average of the best results gave ·00000114 small calories per second per square centimeter per degree, for a thickness of 1^{cm} of the radiating layer.

In 1900, Professor Very published an extended monograph on the subject, in which very numerous experiments of his own and others are collected and discussed with the utmost skill and patience. Very's result, stated in the terms given above, at 100° excess temperature, was ·00000036, or three times smaller than what we had obtained. The large difference led to a reëxamination of our figures and methods without finding anything that could account for it. An entire change of apparatus and method often leads to unexpected results, and may cause us to modify our views as to the probable error of our former consistent figures. In 1902, we constructed an entirely new apparatus, containing nothing that belonged to the old. A radio-micrometer after Boys was the heat-receiving instrument. We avoided all suspicion of air contamination by taking air from out-of-doors. A box some 6 feet long, 2·5 feet wide, and 3 inches deep, containing a sheet-iron bottom about half-way up, and covered with a single sheet of glass, was set at an angle of about 45° outside a south window. The upper end of the box was extended by a wooden chimney that projected through a slit in the window shutter. The box had trunnions at the sides upon which it could be tilted by pulling a string. The radio-micrometer was mounted inside the shutter, so that in the lowest position of the chimney the current of air that streamed up through came opposite the radio-micrometer opening. Sunlight falling upon the exposed glass cover heated the sheet-iron bottom, and this in turn heated the air in contact with it, and a current of hot air was delivered through the chimney. The temperature of the hot air was obtained by a thermal junction of two thin copper and iron wires inserted in the stream, the circuit being completed through a calibrated galvanometer.

On clear, still days, excess temperatures of 50° to 60° of the hot air stream were obtained, and from the deflections produced as compared with those produced by a lampblacked surface at known temperature, we got values of the radiation constant that lay on both sides of the mean result of 1892. Great difficulty was experienced in getting a steady flow of hot air, and the behavior of the radio-micrometer was far from satisfactory. The experiments were discontinued when it was found that nothing new was to be learned by this method. We could at least conclude that the difference between pure air and that contained in an ordinary room with respect to radiating power was inappreciable.

The winter of 1902–3 was spent in improving the radio-micrometer, and an instrument of remarkable sensitiveness and accuracy was produced.*

This season we have taken up the problem anew with much improved apparatus and in very much improved surroundings. The investigation was carried out in the constant temperature room of the Searles Physical Laboratory, and the extreme range of temperature during the weeks of experiment has been less than 2°.

Finding our knowledge of the absorption of air for its own radiation in a very imperfect state, we turned our attention first to that problem.

Description of Apparatus.

The radio-micrometer was mounted upon a massive stone table, and screened from external sources of radiation. In line with the opening of the radio-micrometer was placed a truncated cone of sheet tin, 45^{cm} long, having an opening $1{\cdot}5^{cm}$ in diameter, corresponding to the opening of the instrument, and enlarging to $5{\cdot}5^{cm}$ at the other end. The cone is extended by a cold-drawn seamless brass tube, polished within, 280^{cm} long, and 5^{cm} internal diameter. Over the end of the brass tube is slipped a tin tube 8^{cm} in diameter, held in place by wooden rings and projecting 70^{cm} beyond the brass tube. These 70^{cm} are thickly set with diaphragms, having 5^{cm} openings, and the tube and diaphragms are carefully blackened. The legitimacy of using reflecting tubes for passing along a radiation from a distant source has often been called in question. All doubt should, however, be set at rest by recent experiments made upon the reflecting power of metals bathed in air, for long waves. Hagen and Rubens show† that all metals are practically perfect reflectors for radiations of great wave length, and it is certain that any difference between the reflecting power for air radiation, which is known to be of very great wave length, and the radiation from a lampblacked surface at slight

* This Journal, vol. xv, April, 1903. † Drude's Annalen, vol. ii, p. 873, 1903.

temperature excess, would be inoperative so far as our present purposes are concerned. Opposite the tin tube is placed the device for heating and delivering an air column. A box of wood 100^{cm} by 35^{cm} by 14^{cm} is mounted upon trunnions so as to be tilted by pulling an attached string. In its vertical position, the column of hot air is delivered centrally past the opening of the long tube, but upon releasing the string the box tilts back out of the way. Beyond the air column stands a large blackened copper cube filled with water at the room temperature, and to this all temperatures are referred.

The box is filled with coils of iron wire which are heated by a current taken from the lighting circuit, and the air flowing up through them is heated in turn. The temperature of the hot air is given by a thermometer having a very small bulb held in the stream at the height of the opening in the long tube.

Experiment to determine the Absorption in the Long Tube for Lampblack Radiation.

As our values of air radiation were to be obtained in terms of radiation from a lampblacked surface, it became necessary to inquire whether the column of air in the long tube exerts any appreciable absorption upon the lampblack radiation. Langley, in his work on the temperature of the moon, has shown that a column of air 110 meters deep absorbs about 20 per cent of the rays from a blackened surface at 100° C. If the absorption follows Lambert's law, it would, in a column of air 245^{cm} deep—the depth used in the following experiment—be about 0·5 of one per cent, and may be neglected. The object of the following was to ascertain if the absorption changes with temperature excess.

A second blackened tank at a higher temperature than the standard tank was thrust in front of the tube and the deflection of the radio-mircometer noted. The following table gives the results.

TABLE I.

Depth of absorbing column, 245^{cm}.

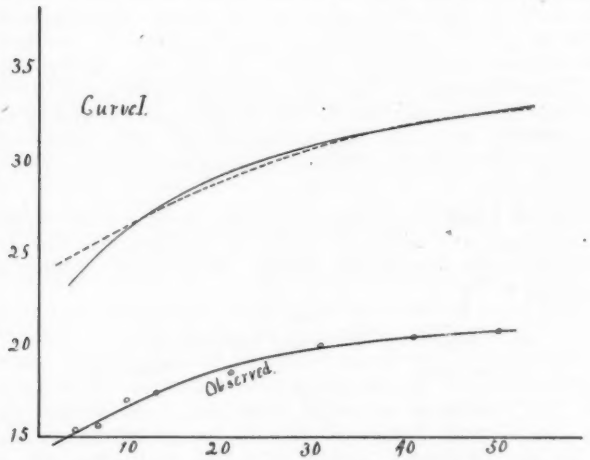
Excess Temp.	Mean Defl.
4°·06	62·6
6·62	103·5
9·55	163·0
12·79	224·0
12·18	51·63
20·91	94·17
30·60	145·3
40·90	200·3
50·00	252·5

The sensitiveness of the instrument was changed by withdrawing the condensing mirror at the point marked by the horizontal line through the table. To reduce all to a common scale, we need a reduction factor for change of sensitiveness. This will be the ratio of the deflection per degree excess for 12°·79 to the deflection per degree for 12°·18, assuming that the radiation rate is the same for these two near temperatures. After applying this factor and dividing each deflection by its corresponding temperature, we obtain the following:

TABLE II.

Excess Temp.	Defl. per Deg. Exc.
4°·06	15·42
6·62	15·63
9·55	17·07
12·79	17·51
20·91	18·61
30·60	20·01
40·90	20·23
50·00	20·86

M'Farlane gives a table* showing the radiation in small calories per second per square centimeter of a blackened surface. For 50° excess, M'Farlane's figure is ·000326. Multiply-



ing the number in the second column of Table II by such a factor as will reduce the last to ·000326, we plot a curve with excess temperatures as values of x, and the observed radiation rates, derived as above, as values of y, and along with it, a second curve from M'Farlane's observations.

* Proc. Roy. Soc, 1872, p. 93.

M'Farlane's curve is dotted. It will be seen that there is nothing shown by the above results from which increased absorption at small excess temperatures can be argued. Considering the widely different methods by which these curves were derived, their agreement is quite striking. We feel sure then that we shall commit no appreciable error in effecting a comparison of air and lampblack radiation if we assume that the latter is unabsorbed by columns of air of the depth used in our experiments. In fact, difference in the manner of preparation of the lampblack surfaces is known to cause greater radiation differences than are shown here.

Absorption of Air for its own Radiation.

The radiation of air cannot be properly considered apart from the question of the rate at which its own radiation is absorbed. Very* obtains a change of deflection per foot of increase in radiating depth of 8·3, 10·0, 8·2, 10·4, −1·2, the depths being 1, 2, 3, 4, and 5 feet, respectively. Disregarding the rather discordant character of these figures, he rejects the negative change for 5 feet entirely on what seems somewhat uncertain grounds. We have sought to avoid the difficulty of absorption in the radiating column itself by measuring the depth of the absorbing layer from the center of a radiating column only 10^{cm} deep; hence if there be any outstanding error, it must be very small and we believe negligible.

A complete example of the method of proceeding is here given. The long tube being in place and carefully covered with asbestos steampipe covering, the current was turned on in the heating box and at the end of half an hour the following deflections were obtained:

TABLE III.

Defl.	
55·	
52·	Date, June 29
54·5	
53·	Air column, 491^{cm}
55·5	
55·5	Hot air temp. 142°
52·	
55·	Room temp. 20·5
56·	
Mean 54·33	Hot air exc. 121·5

*Atmospheric Radiation, p. 45.

The warmed blackened tank gave the following deflections:

TABLE IV.

Temp. cold tank.	Temp. hot tank.	Deflections.
20·56	24·05	106·
	24·10	101·5
	24·18	109·5
	24·22	106·5
20·58	24·24	104·5
20·57	24·16	105·6

The mean deflection corresponding to 1° excess temperature of air is

$$\frac{54{\cdot}33}{121{\cdot}5}=0{\cdot}4472.$$

The excess temperature of the lampblacked surface is

$$24{\cdot}16-20{\cdot}57+0{\cdot}59=4{\cdot}18$$

where +0·59 is the thermometer correction. Hence the deflection per degree excess for the lampblacked surface is

$$\frac{105{\cdot}6}{4{\cdot}18}=25{\cdot}26.$$

Finally, the ratio of the hot air radiation to that from the blackened surface is

$$\frac{{\cdot}4472}{25{\cdot}26}={\cdot}01770.$$

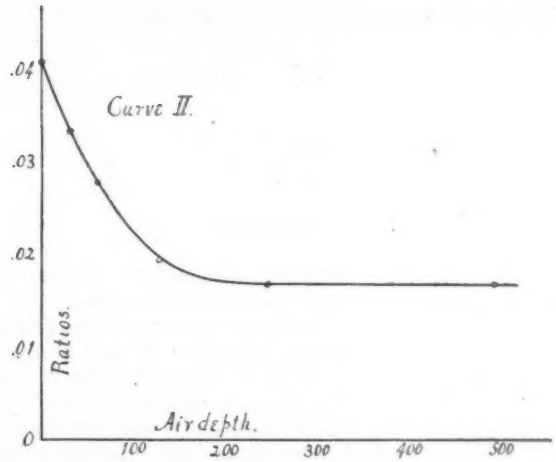
On July 1, we obtained ·159; on July 2, 0·177; on July 8, 0·1734; the average of six days being 0·1685.

The absorbing column was then made 245^{cm}, 127^{cm}, 61^{cm}, and 30^{cm}, and the same method followed for each distance, in each case the observations being distributed over several days. The results are tabulated below:

TABLE V.

Absorbing column	Mean Ratio
30^{cm}	·0332
61	·0278
127	·0195
245	·0169
491	·0168

Plotting these observations with the numbers in the first column of Table V as abscissas and the numbers in the second column as ordinates, we obtain the following curve:



An inspection of this curve reveals a very important feature of air radiation hitherto unknown; namely, that some 60 per cent of its own radiation is absorbed by a column as thin as 245^{cm}, the remaining 40 per cent being freely transmitted as though coming from a black body. We have plotted the ratios of air radiation to lampblack radiation per degree excess temperature. The point where the curve cuts the Y-axis will correspond to the ratio at zero depth of absorbing column, and is important to know. This point may be calculated as follows:

Let L = radiation from lampblack
b = radiation of air for which absorption is neglected
J′ = Characteristic radiation from hot air, that is, b neglected
Then at zero depth, $b+J'$ is the total radiation from air. Lambert's law is $J=J'a^b$, and we have plotted the quantity $\frac{b+J'}{L}$ versus d. Taking $d_1=1$, and $d_2=2{\cdot}033$, we have

$$\frac{b+J_1}{L}=0{\cdot}0332=\frac{b+J'a}{L}, \tag{1}$$

$$\frac{b+J_2}{L}=0{\cdot}0278=\frac{b+J'a^{2{\cdot}033}}{L} \tag{2}$$

$$\frac{b}{L}=0{\cdot}0169 \tag{3}$$

We wish to find the value of $(b+J')/L$.
From (3), $b=0{\cdot}169\ L$
whence, from (1), $J'a=0{\cdot}0163\ L$
and $a=0{\cdot}0163\ L/J'$

Substituting the values of a and b in (2), we get

$$0{\cdot}0109\ \mathrm{L} = \frac{(0{\cdot}0163\ \mathrm{L})^{2.033}}{(\mathrm{J}')^{1.033}}$$

whence $$\mathrm{J}' = \mathrm{L}\left[\frac{(0{\cdot}0163)^{2.033}}{0{\cdot}0109}\right]^{\frac{1}{1.033}}$$

This gives $$\frac{b + \mathrm{J}'}{\mathrm{L}} = 0{\cdot}0409.$$

This point fits in a perfectly satisfactory manner upon a smooth curve drawn through the observed points.

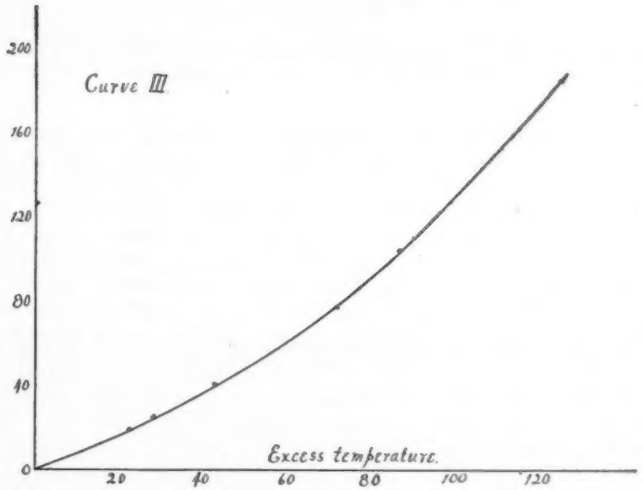
What the course of absorption may be beyond a depth of 500^{cm}, we have no means at present of judging. It may be suggested that the compound nature of air is responsible for its peculiar manner of absorption. Perhaps its contained water vapor is the substance radiating like a black body, and that apart from this, the strongly curved portion of our diagram shows the characteristic behavior of its prominent gaseous constituents. If this be true, it follows that the radiation of pure dry air is effective only at comparatively slight depths. The amount of moisture in the air during this course of experiments was considerable, the relative humidity not varying much from 78·2. It may be that water vapor so little removed from its point of saturation no longer behaves as a true gas, but as an aggregate of particles, in which case it would transmit all rays with considerable freedom, the particles producing a scattering effect merely. The accepted explanation of the color of the sky favors this view.

We have now to discuss the change of radiation of air with change of temperature. By introducing a variable resistance into the circuit of the heating box the temperature of the heated air could be changed at will. A mean of five to ten consistent observations was taken for each temperature and the results tabulated as follows:

TABLE VI.

Exc. Temp.	Mean Defl.
22°·5	18·55
28·2	24·9
43·2	40·9
72·1	77·9
87·0	105·7
125·5	185·9

Plotting deflections versus temperatures from Table VI, we obtain the following curve:



Calling D the deflection and t the temperature, the equation of this curve may be written,

$$D = At + Bt^2 + Ct^3$$

From which, using three observations, we obtain,

$$D = \cdot 7185\ t + \cdot 486\ t^2\ (10^{-2}) + \cdot 96\ t^3\ (10^{-5})$$

the logarithmic coefficients being

$$\log A = 9 \cdot 856448 - 10$$
$$\log B = 7 \cdot 687127 - 10$$
$$\log C = 4 \cdot 984735 - 10$$

From the above the relative ratio of air radiation per degree at different temperatures may be found.

$$\text{For } t = 1°, \text{ we have } dD/dt = 0 \cdot 728$$
$$\text{For } t = 100°, \qquad dD/dt = 1 \cdot 98$$

Hence the radiation per degree at 100° is $1 \cdot 98/0 \cdot 728 = 2 \cdot 72$ times greater than at 1°.

There remains before computing the value of the radiation constant to find the temperature gradient of the hot air column in the line of sight; laterally, the central portion of the air column only was used and no correction in that direction is required. A thermal junction of thin copper and iron wires was moved by steps through the heated air column, and the readings of a galvanometer, through which the junction was connected, noted. The edge of the opening in the air chimney being called 0, its center would be at 5. The following readings were obtained:

TABLE VII.

Dist.	Defl.
5·0	155
4·0	155
3·0	155
2·0	155
1·0	149
0·5	124
0·2	105
0·0	90
−0·2	75
−0·5	50
−1·0	22

The air flowing up past the outside of the warmed box gave the deflections for negative values of distance; the integral of these was nearly sufficient to balance the loss for less temperature within the range of positive values of the distance. By plotting a curve and integrating the positive and negative values with reference to distance, and radiation rate as derived from Curve III, we find the actual air column to be 0·967 as effective as a column 10^{cm} deep, and at a temperature measured at its center.

We are now prepared to calculate the radiation constant, h. Assume that this is wanted for an excess temperature of 100°, a depth of 1^{cm}, and zero absorbing column. We have:

Ave. of all exc. air temps. observed = 122°
Defl. for 122° from Curve III = 179
" " 100° " " " = 130
Rad. per deg. from lampbl. at 4° exc. (avg.) = ·000249 (M'Farl.)
Ratio of air to lampblack radiation for zero absorbing column, from Curve II, = ·041
Therefore $h = (130/179)(\cdot000249)(0\cdot1)(\cdot041)(0\cdot967)$
$= 0\cdot000000717$ water-gram-degrees per sq. cm. per sec. per deg. exc. temp.

For 1°, this becomes 0·000000264, and may be found with great facility from the curves given, or from their equations, for any temperature or depth of absorbing column within the limits of our observations.

If our surmise be correct that the freely transmitted part of moist air radiation is from its contained water vapor, amounting to 40 per cent of the whole, then the above numbers would become for dry air, 0·00000043 and 0·00000016, respectively.

Bowdoin College, July, 1904.

Art. XXXII.—*Uintacrinus and Hemiaster in the Vancouver Cretaceous;* by J. F. Whiteaves.

Very few remains of echinodermata have hitherto been found in the Cretaceous rocks of Vancouver and the adjacent islands. Those enumerated in the latest and most complete list of the fossils of these rocks, published by the Geological Survey of Canada in 1902, are only fragments of the test of a regular echinid; portions of the ray of a five-rayed starfish; a five-lobed joint of the column of a pentacrinite; and a fragment of the basal portion of the dorsal cup of a crinoid. Although three of the classes of echinodermata were then known to be represented in these rocks, it was by such fragmentary specimens that it was scarcely possible to determine them, even generically.

But, in a collection of Cretaceous fossils from various localities on or near Vancouver Island, recently sent to the Museum of the Canadian Geological Survey by Mr. Walter Harvey, there are two fairly good specimens of a crinoid, and as many as forty of a spatangoid or heart urchin.

The two crinoids evidently belong to the same species, and are obviously referable to the sessile genus *Uintacrinus*, Grinnell.

One of them is a comparatively large cast of the interior of a dorsal cup, crushed nearly flat, upon a piece of brittle shale from the north bank of the Cowichan River, V. I., about a mile above the bridges at Duncan's, collected by Mr. Harvey in 1903. It is well preserved and shows a monocyclic base, with an undivided centrale, five small basals, five large radials, the third circlet of plates, and a few plates of the fourth. In their shape and arrangement, the whole of these plates correspond very well with those of some regular, monocyclic specimens of the dorsal cup of *Uintacrinus*, as figured in the latest memoir on that genus by the Hon. Frank Springer (1901) and as shown in some fine specimens of *U. socialis* from Kansas, kindly forwarded by Mr. Springer for comparison.

The other specimen is a small, badly preserved and rather worn cast of the interior of a calyx, also crushed nearly flat, from similar shales about a mile south from Vesuvius Bay, Salt Spring Island, in the Strait of Georgia, collected by Mr. Harvey in 1902.

Both of these specimens are clearly referable to the genus *Uintacrinus*, but they are scarcely sufficiently perfect for specific determination or description, though it must be admitted that they show no characters by which they can be

satisfactorily distinguished from some forms of the typical and very variable *U. socialis.*

In Utah and Kansas *Uintacrinus* is said to have been found only in the Niobrara chalk, but the exact equivalent of that subdivision of the Upper Missouri section has not yet been recognized in the Nanaimo group of the Vancouver Cretaceous. The specimens of *Uintacrinus* from Vancouver and Salt Spring islands are from the lower beds of the Nanaimo group, below the coal, and it has yet to be ascertained whether the genus occurs at a little higher geological horizon than the Niobrara at those islands, or whether the supposed lower beds of the Nanaimo group may not at some places represent or include the Niobrara. In the Queen Charlotte Islands the "Upper shales and sandstones, or subdivision A, of Dr. G. M. Dawson's Report" on these islands, which hold *Inoceramus labiatus (problematicus)* are supposed to represent the Niobrara.

The spatangoids are casts of the interior of the test of a species of *Hemiaster*, from shales and sandstones of the Nanaimo group, at four localities on Vancouver Island and one on Salt Spring Island. Many of these casts are distorted and crushed out of shape, but others are well preserved and very little if at all distorted. Two of them, in particular, are almost perfect and very well preserved, and both of these have recently been presented to the Museum of the Canadian Geological Survey. One of them, the first that was obtained, was found by Miss Wilson, in 1897, on the north bank of the Cowichan River, V. I., near Menzies Creek; and the other by Mr. Harvey, in 1903, at Shopland, V. I. Mr. Harvey writes that he has found specimens of this heart urchin all over the Cowichan coal-field, V. I., at the northeast end of Salt Spring Island, and at Crofton, V. I., the most southerly point of the Nanaimo coal-field, in 1902, 1903 and 1904.

Only one species of *Hemiaster* has previously been recorded as occurring in the Cretaceous rocks of North America. This is the *H. Humphreysanus*, from the Fort Pierre or Montana formation of the Upper Missouri country, and district of Athabaska, which was first described by Meek and Hayden in 1857, and re-described and figured by Meek in 1876. But the fauna of the Cretaceous rocks of the Pacific coast is in many respects different to that of their representatives in the great interior plateau, and the Vancouver *Hemiaster* seems to differ from *H. Humphreysanus* in its much more depressed and widely suboval or subovate form. It may be provisionally named and described as follows:

Hemiaster Vancouverensis, sp. nov.

Cast of the interior of the test widely suboval or subovate in marginal outline, a little longer than wide, and widest at or a little in advance of the midlength, with the posterior end abruptly and almost vertically truncated in some specimens but not so much so in others. Dorsal or abactinal surface depressed convex, very slightly elevated, most prominent at a short distance from the posterior end; ventral or actinal surface flattened; greatest height about one-half of the maximum length. Oral aperture not well shown in any of the specimens collected, vent small, a little higher than wide, placed high up on the truncated posterior extremity and near the abactinal surface; apical disc situated at a considerable distance behind the midlength in some specimens, but not very far from median in others. Ambulacra very unequal in length; the odd anterior ambulacrum being a little longer than the anterolaterals, but rather indistinctly defined at the anterior end, and the anterolaterals much longer than the short posterolaterals. Anterior median sulcus shallow but well marked, and giving a faintly emarginate or subemarginate outline to the anterior end. Anterior ambulacrum entirely included within the median sulcus; anterolateral ambulacra petaloidal, narrowly elliptical and shallowly depressed; posterolateral ambulacra also shallowly depressed, somewhat similar in shape to the anterolaterals, but not more than one-half of their length. Spines and exterior of the test unknown.

The foregoing description is based almost exclusively upon the two nearly perfect and undistorted casts from the Cowichan River and Shopland, already referred to, and these may therefore be regarded as the types of the species.

Ottawa, August 23, 1904.

ART. XXXIII.—*The Separation of the most Volatile Gases from the Air without Liquefaction;** by Sir JAMES DEWAR.

[Read before the Royal Society of London, June 16, 1904.]

FROM the time when liquid air came to be an ordinary laboratory agent I have continually used it for the purpose of producing high vacua in vessels that had been previously filled with easily condensable gases, like sulphurous acid, carbonic acid, vapor of water or benzol.

When the liquefaction of hydrogen was effected, one of the first scientific uses to which it was put was that described in my paper on the "Application of Liquid Hydrogen to the Production of High Vacua, together with their Spectroscopic Examination."† In that communication it was shown by theory and confirmed by experiment that the condensing power of liquid hydrogen is so great relatively to that of liquid oxygen or nitrogen, that any closed vessel, a part of which is cooled to the boiling point of hydrogen, must suddenly become a highly vacuous space. This was proved by the great difficulty of getting electric discharges to pass through specially prepared spectroscopic tubes when subjected to liquid hydrogen cooling, and from the fact that when the current did pass no lines of oxygen or nitrogen were seen, but only those of hydrogen, helium and neon. In order to separate these latter gases from air it was necessary to liquefy a quantity of air and to distill off the most volatile portion at as low a temperature as possible into a separate receiver placed in liquid hydrogen. In this way many spectroscopic tubes were filled with the uncondensable air gases and the results of their examination is recorded in a paper entitled "On the Spectra of the more Volatile Gases of Atmospheric Air, which are not condensed at the Temperature of Liquid Hydrogen,"‡ by Professor Liveing and myself.

Some two years later I improved the method of separation of the volatile air gases. The process is fully described and illustrated in my paper on "Problems of the Atmosphere."§ Its success depends upon the continuous direct liquefaction of air at atmospheric pressure combined with a device which

* From an advance proof sent by the author.
† Proc. Roy. Soc., vol. lxiv, 1898.
‡ Proc. Roy. Soc., vol. lxvii, 1900.
§ Proc. Roy. Inst., 1902.

enables the more volatile gases to be trapped and separated. In this way some 1/35,000th of the volume of the air liquefied is collected as a gaseous mixture, having the composition 38 per cent of nitrogen, 4 per cent of hydrogen, and 58 per cent of mixed helium and neon. After sparking to remove the nitrogen and hydrogen a gaseous mixture of helium and neon containing a little argon was obtained. This mixture had the composition of 16 per cent helium and 84 per cent neon. In both methods of treatment it will be noted the liquefaction of the air was the essential preliminary operation, to be supplemented in the one case by the use of liquid hydrogen, in the other by sparking to remove the nitrogen. The paper already communicated to the Royal Society,* entitled "The Absorption and Thermal Evolution of Gases Occluded in Charcoal at Low Temperatures," in which the greatly increased power of occlusion possessed by charcoal at low temperatures is proved, suggested an inquiry into the limits of gaseous pressure reached by such means of condensation.

With this object a narrow tube CE, fig. 1, was sealed to an ordinary spectroscopic sparking tube AB, and at the end E an enlarged space was blown out capable of holding a few grams of cocoanut charcoal. After the charcoal had been freed from gases by heating and exhaustion and the poles cleared by sparking during this operation, pure and dry gases like oxygen, nitrogen, air, carbonic oxide, hydrogen, neon and helium could be admitted at different pressures and the tube with its charcoal chamber attached sealed off.

On placing the charcoal end of the apparatus in liquid air, the gas in each case was rapidly absorbed and the vacuum produced reached the phosphorescent stage in all cases with the exception of hydrogen, neon, and helium. A small Crookes' radiometer, full of air at atmospheric pressure, with charcoal tube attached, became quite active to heat radiation when the charcoal was cooled for half a minute in liquid air. To test the amount of exhaustion reached by the use of a given weight of cocoanut charcoal, I sealed on a tube containing 30 grams to a large electric discharge tube of 1300 c.c. capacity filled with air at atmospheric pressure. On cooling the charcoal receptacle in liquid air the pressure diminished to 50^{mm} of mercury. Repeating the same experiment but starting with the tube initially at half an atmosphere, the exhaustion reached was now beyond the striæ stage. A further experiment starting with one-fourth of an atmosphere gave a vacuum through which no discharge passed.

Finally, the 30 grams of charcoal were replaced by only 1 gram and the initial pressure was reduced to 3^{mm} of mercury.

* This Journal, p. 295 following.

Now the vacuum just reached the beginning of the phosphorescent stage. With hydrogen, either a pressure of gas less than that of the atmosphere had to be used at starting or a larger amount of charcoal employed in order to get a vacuum well up in the striæ stage. If, however, the liquid air was cooled to $-210°$ C. by exhaustion, the tube just reached the beginning of phosphorescence round the cathodes.

With helium there was a very slight absorption, but neon did show something more appreciably. Spectroscopic observations made during the condensation of the gas in the charcoal showed the gradual disappearance of the characteristic spectrum of oxygen, nitrogen and air, as the high vacuum was reached and the discharge passed with great difficulty. In

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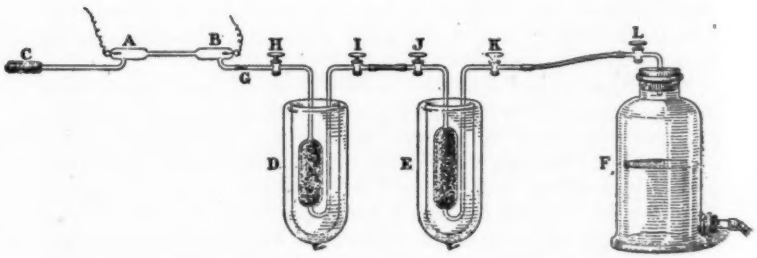

tubes of this kind filled at atmospheric pressure I could always see the F line of hydrogen and the neon yellow; but the helium was not seen with any definiteness. As the amount of neon in the air cannot well exceed 1/50,000th the spectroscopic test is very delicate.

In order to bring in the helium lines it was necessary to concentrate the volume of air in the space of the sparking tube six or seven times. This was done by the use of an arrangement shown in fig. 2. AB is the sparking tube with its small charcoal bulb C attached, capable of being sealed off when required at G; and D and E are larger charcoal absorbers placed in vacuum tubes containing liquid air; the whole being attached to a graduated gas-holder containing air. A series of glass stop-cocks are attached at the points H, I, J and K in order to facilitate manipulation. In determining the volume of air required to bring in the helium lines, only one charcoal absorber containing about 15 grams of material was used. On allowing 200 c.c. of air from the gas holder to be sucked into the charcoal (which had been previously exhausted along with the sparking tube) on opening the stop-cock H any residuary

gas in D was swept into the sparking tube, which was then sealed off at G.

This tube gave the hydrogen lines C and F, the neon yellow, and some of the orange lines, along with the helium yellow and green quite distinct. With the residuary gas extracted from one liter of air I could see all the helium lines. On the positive pole the neon yellow and the green of helium were alone marked, while the negative pole gave both the neon and helium yellow lines along with the helium green and the F of hydrogen on the continuous spectrum. From this it would appear that the spectroscopic test for helium is as delicate as that for neon, and that 1/50,000 can be recognized. From 3 liters of air discharge tubes were obtained, giving the neon and helium spectra associated with a brilliant ruddy glow discharge.

As 40–50 grams of charcoal can absorb at the temperature of liquid air from 5–6 liters, it is easy to accumulate rapidly the uncondensed gases in considerable quantities for spectroscopic examination. For this purpose I found it convenient to use two charcoal condensers in circuit as represented in fig. 2. After the charcoal in the first one marked E was saturated, the stop-cock K was closed, while I and J were opened for a short time so as to allow the less condensable gas in E to be sucked into the second vessel of the same type D along with some portion of air. The charcoal condenser E was then taken out of the liquid air, and rapidly heated to 15° C. in order to expel the occluded air. It was thus in a condition to repeat the absorption. In this way 50 liters of air can be treated in a short time. Sparking tubes filled from the accumulated gases in D were very brilliant, showing the complete spectrum of the volatile constituents of air. It is hardly necessary to remark that after the little charcoal receptacle connected to each of the sparking tubes has been cooled and thus all traces of air absorbed, it can be sealed off, leaving the spectroscopic tubes intact. The complete spectroscopic study of the products must be left for further examination with Professor Liveing.

The method I have described will be equally applicable to the treatment of the gaseous products from minerals containing helium, hydrogen, etc., and also to the radium products of a similar kind. It seems even probable that the separation of the less volatile constituents in air may be improved by a slight modification in the mode of working. The behavior of the gases from the Bath Springs has been examined. When the gas containing 1/1000th part of helium in what may be regarded as pure nitrogen is subjected to charcoal absorption exactly in the same way as the air was treated, no high vacuum

is reached. All the nitrogen and any other constituents disappear, and a spectrum of helium and hydrogen, showing much less neon than exists in the volatile residue from atmospheric air, is the result. A sample of argon made from Bath gas gave, when the argon was absorbed in charcoal, a gas residuum giving the helium and neon spectrum, and the same result follows the use of atmospheric argon. In the case, however, of the Bath gas argon the helium spectrum is the stronger, whereas with air argon the neon is the most pronounced.

In order to further test the method, the crude gases got by heating the mineral fergusonite were examined. During the cooling of the charcoal the nitrogen and hydrogen spectra were marked, but in a short time nothing could be seen but the lines of hydrogen and helium.

Great interest will attach to the behavior of helium, hydrogen and the most volatile part of air, when subjected to the action of charcoal cooled to the temperature of liquid hydrogen. The method promises to open up many avenues for future inquiry.

ART. XXXIV.—*The Absorption and Thermal Evolution of Gases occluded in Charcoal at Low Temperatures;* by Sir JAMES DEWAR.*

[Read before the Royal Society of London, June 16, 1904.]

DURING the year 1874–5, in association with the late Professor Tait, a research was undertaken which involved the production of very perfect vacua, and with the object of improving on the then known methods, dense charcoal was employed as an efficient absorbent of traces of any gaseous residuum. An account of these experiments communicated to the Royal Society of Edinburgh appeared in Nature, July 15, 1875, under the title of "Charcoal Vacua."

In Professor Clerk Maxwell's Notes on "Molecular Physics" the following succinct description of the process is given: "Another method employed by Professor Dewar is to place in a compartment of the vessel a piece of freshly heated cocoanut charcoal, and to heat it strongly during the last stages of the exhaustion by the mercury pump. The vessel is then sealed up, and as the charcoal cools it absorbs a very large proportion of the gases remaining in the vessel.

"The interior of the vessel, after exhaustion, is found to be possessed of very remarkable properties. One of these properties furnishes a convenient test of the completeness of the exhaustion. The vessel is provided with two metallic electrodes, the ends of which within the vessel are within a quarter of an inch of each other. When the vessel contains air at the ordinary pressure a considerable electromotive force is required to produce an electric discharge across this interval. As the exhaustion proceeds, the resistance to the discharge diminishes till the pressure is reduced to that of about a millimeter of mercury. When, however, the exhaustion is made very perfect the discharge cannot be made to take place between the electrodes within the vessel, and the spark actually passes through several inches of air outside the vessel before it will leap the small interval in the empty vessel. A vacuum, therefore, is a stronger insulator of electricity than any other medium."

At one of the conferences held in connection with the Special Loan Collection of Scientific Apparatus† in the year 1876, I showed that with a vapor like bromine the absorptive power of the charcoal was so effective that a space filled with

* From an advance proof-sheet by the author.

† See Science Conferences, Physics and Mechanics, p. 154.

the vapor even at atmospheric pressure could be made into a fairly high vacuum showing very wide striæ. When the charcoal was heated the bromine vapor was again expelled, and on allowing it to cool, all stages in the appearance of the electric discharge as the vacuum is reached could be conveniently observed without the use of any form of air-pump.

When in the course of low temperature investigations the perfection of the vacuum vessels for the storage and manipulation of liquid air and hydrogen came to be important, the effect of charcoal on heat isolation in such utensils was fully

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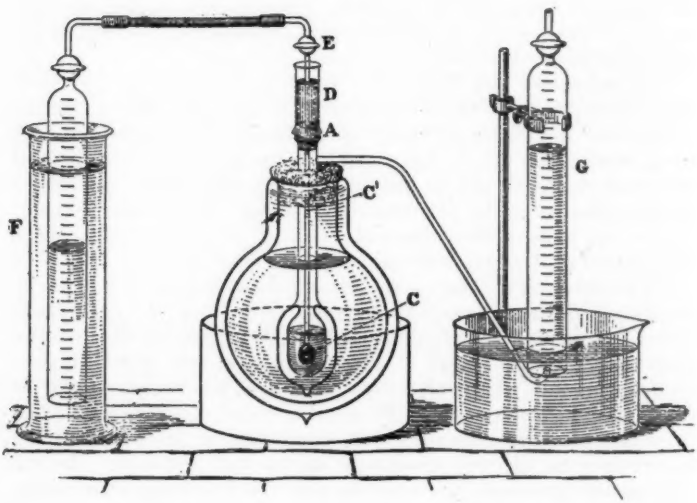

investigated and confirmed in a paper entitled "Liquid Air as an Analytic Agent."* Still no systematic experiments on the absorptive power of charcoal at low temperatures were made either at this time or subsequently.

It is the object of the present preliminary paper to contribute some definite quantitative data regarding gas absorption and thermal evolution in charcoal at the temperature of liquid air. The mode in which liquid gases like oxygen or air could be used as calorimetric agents was described in my paper on the "Scientific Uses of Liquid Air."†

* Proc. Roy. Inst., 1898.
† Proc. Roy. Inst., 1894.

The apparatus was further improved into the form illustrated and described in Madame Curie's Work, "Recherches sur les Substances Radio-Actives," 2d edition, p. 100, as used for the determination of the heat evolved by radium bromide either in liquid oxygen or hydrogen. Such calorimeters are easily adapted to the simultaneous observation of the volume of any gas absorbed by charcoal, and of the concomitant heat evolution.

For this purpose a small glass bulb C (fig. 1) containing from 0·5–1 gram of charcoal has a long narrow tube C' attached, so that it can be immersed in the liquid oxygen or air in the calorimeter A B, while still allowing a part of the tube to project above the cork A. In order to dry and cool the 40 c.c. of gas, which represents the largest volume taken in by the charcoal in my experimenfs, a little annular space is arranged at D into which liquid air is poured immediately before the experiment is made.

The charcoal, after being placed in the tube C, is heated to a low red heat and simultaneously exhausted by a good air-pump, and after all the gas has been removed the stop-cock E is closed. In this condition it is placed in the calorimeter.

The experiment is conducted by connecting the end of the tube at E by means of an india-rubber tube with a graduated vessel F containing the gas. When all is ready the stop-cock E is opened, so that the gas may rush into the charcoal, and the heat evolved by its absorption distills off the equivalent quantity of liquid air from the calorimeter, which is measured in the vessel G.

The constant of the calorimeter being known (which with liquid air is about 14·5 c.c. per calory), we get the actual thermal evolution together with the volume of gas absorbed.

The heat correction for the rush of gas into the same exhausted glass bulb without charcoal is small in proportion to the total heat evolved, and the same may be said of the volume correction on account of the cooling of the space external to the charcoal. With a variable material like cocoa-nut charcoal I have in the calorimetric experiments used the same sample in all cases. The following table embodies the general results per cubic centimeter of charcoal. The gas absorption is given at 0° and 760^{mm}. If the volume of gas absorbed had been measured under the same conditions of pressure at −185° C., then the numbers in Column II would all have to be divided by three.

	I. Volume absorbed. 0° C.	II. Volume absorbed. −185° C.	III. Heat evolved. Gram-calories.
Hydrogen	4 c.c.	135 c.c.	9·3
Nitrogen	15 "	155 "	25·5
Oxygen	18 "	230 "	34·0
Argon	12 "	175 "	25·0
Helium	2 "	15 "	2·0
Electrolytic gas	12 "	150 "	17·0
Carbonic oxide and oxygen	30 "	195 "	34·5
Carbonic oxide	21 "	190 "	27·5

In all cases, it will be observed, the amount of gas occluded has been greatly increased at the low temperature, and the degree of condensation is generally such as we should anticipate from the known physical constants of the gases. The amount of heat evolved is so great as to be in excess of that required for liquefaction in the case of gases like hydrogen, nitrogen, and oxygen. The heat produced when successive fractions of the volume of gas required for saturation are absorbed has yet to be determined. In the time required for the absorption no measureable amount of chemical combination was effected between mixtures of hydrogen and oxygen or carbonic oxide and oxygen in the pores of the charcoal.

Such experiments must be extended to the use of platinized charcoal and other catalytic agents.

Perhaps the most striking result is the great difference in properties exhibited by helium. While resembling the other gases in showing increased absorption at the temperature of liquid air, the absolute amount occluded per unit volume of charcoal is about one-tenth that of the other gases at the same temperature. There can be little doubt that when the relative absorption of helium in charcoal is measured at the temperature of liquid hydrogen, the increased absorption will be so marked as to make it comparable to that of hydrogen in the present set of experiments. In this case charcoal at the boiling point of hydrogen will become an efficient condensing agent for helium, and this property will have important applications in future research.

Separation of Highly Concentrated Oxygen from Air.

In order to examine the changes taking place in a mixed gas like air during the absorption, a quantity of about 50 grams of charcoal was, after heating and exhaustion, saturated at −185° in a current of pure dry air; got by passing the air current through a U-tube immersed in liquid air.

For a time the air rushed into the charcoal with great rapidity, and in about 10 minutes between 5 and 6 liters were taken in.

A manometer attached to the vessel containing the charcoal showed, on shutting off the air current, that during the early part of the saturation the absorption was so effective as to give practically no measurable mercury pressure. As soon as the absorption was ended, and a current began to pass slowly over the charcoal, the composition of the air leaving the charcoal showed 98 per cent nitrogen. After the current of air had passed for half an hour, the total gas occluded in the charcoal was expelled by taking the vessel in which it had been treated out of the liquid air, and allowing the temperature to rise to 15° C.

The gas, which was rapidly expelled, measured 5·7 liters, and contained 56 per cent of oxygen. If the saturated charcoal before heating up was subjected for an hour to the action of an air-pump, capable of giving a steady exhaustion of 5^{mm}, no difference was effected in the oxygen percentage of the evolved gas. The same experiment was repeated with this variation, that, instead of the air current having the pressure of the atmosphere, it was kept below one-tenth of an atmosphere. In this experiment, 4·8 liters were expelled on heating up, and the percentage of oxygen was 58. Then a further repetition was made with an air current supplied at a pressure not exceeding 5^{mm} of mercury. After 3 hours' treatment, the charcoal, on heating to 15° C., gave 4½ liters of 57 per cent oxygen. From these experiments it follows that the tension of the occluded gases, at the temperature of liquid air, must be very small, and thus the use of low temperatures, combined with charcoal, introduces a new and greatly improved means of getting high vacua, which in the future may be found susceptible of important practical applications. These experiments are quite conclusive as to the practical constancy of the mean composition of the air gases occluded in the charcoal (subject to the conditions aforesaid), and they further show that wide changes in the pressure of the air current has little or no effect in altering the proportions. In another experiment, the vessel containing the saturated charcoal, instead of being allowed to rise rapidly in temperature, was transferred to a vacuum vessel, in which a little liquid air was placed, in order that the temperature might rise slowly, and thereby enable the successive liters of gas given off to be collected separately and analyzed.

This experiment gave the following results:—

	Oxygen per cent.
First liter	18·5
Second "	30·6
Third "	53·0
Fourth "	72·0
Fifth "	79·0
Sixth "	84·0

The mean composition of the 6 liters is again 56 per cent oxygen. From the above experiments it follows that one of the most rapid means of extracting a high percentage of oxygen from atmospheric air is to absorb it in charcoal at low temperatures, and then to expel it either rapidly or slowly by heating the mass of charcoal to the ordinary temperature.

A few experiments have been made using, instead of air, special mixtures of oxygen and nitrogen. Thus it was found that a gas containing 6·5 per cent of oxygen used in the same manner as in the air occlusion experiments, gave, on heating up the charcoal rapidly to 15° C., 5 liters of gas having the composition of 23 per cent. of oxygen. A repetition of the same process with the 23 per cent of oxygen would have raised the percentage about 60 per cent, or a stronger concentration could have been reached by fractionating the gas as it slowly leaves the charcoal on gradually increasing the temperature.

This preliminary investigation suggests many fields for future inquiry, and some of these I hope to deal with in future papers.

ART. XXXV.—*Studies in the Cyperaceæ;* by THEO. HOLM.

XXIII. The Inflorescence of Cyperus in North America. (With figures in the text.)

A GENERAL consideration of the structure of the inflorescence in *Cyperus* must necessarily result in the conclusion, that throughout the genus the structure is most essentially the same. The components are invariably the same: the involucral leaves, the prophylla, the branches, the floral bracts and the flowers, all these are clearly represented in each species; nevertheless some differences in aspect are frequently quite obvious, but depend to a very large extent simply upon mere variations in the length of the inflorescential branches, in the position of the spikes, their external shape and the manifold structure of the small, floral bracts.—Some of these characters, however, are often deceptive; because in the same species, it is not unusual to meet with individuals in which the number of spikes is reduced to one or two, nearly sessile, with the involucral leaves and prophylla very inconspicuous, while typically developed specimens may possess an ample inflorescence with long leaves and tubular prophylla.

The division of the genus in sections: *Pycreus*, *Cyperus* proper, *Papyrus*, *Diclidium* and *Mariscus*, is not directly based upon deviation in respect to the real components of the inflorescence, but only in regard to the structure of the spikes and the flowers, especially the arrangement and direction of the spikes, the shape of the rhachis and the structure of the achenes. The specific distinction is not materially dependent upon the main inflorescence, inasmuch as the same form is to be observed in remote sections of the genus, but here our attention is directed to the color and minor structure of the spikes, which constitute the ultimate divisions of the inflorescence, also, in some cases, to the structure of the rhizome.

In presenting a brief description of the inflorescence of the genus, we freely admit that we have nothing to add to the old, but most excellent one, given by Fenzl in his paper on *Cyperus Jaquini* Schrad,* or to the more recent one by Clarke,† but we wish to bring out a few points relating to the structure and function of the fore-leaves, which deserve some attention and which ought not to be passed by entirely in systematic treatments of the genus, as has been the case in American literature. It is, furthermore, the writer's desire to demonstrate, that some of the foliar organs which are pres-

* Denkschr. Math.-Naturw. Cl. Akad. d. Wiss., Wien, vol. 8, 1855.
† Journ. Linn. Soc., vol. 21.

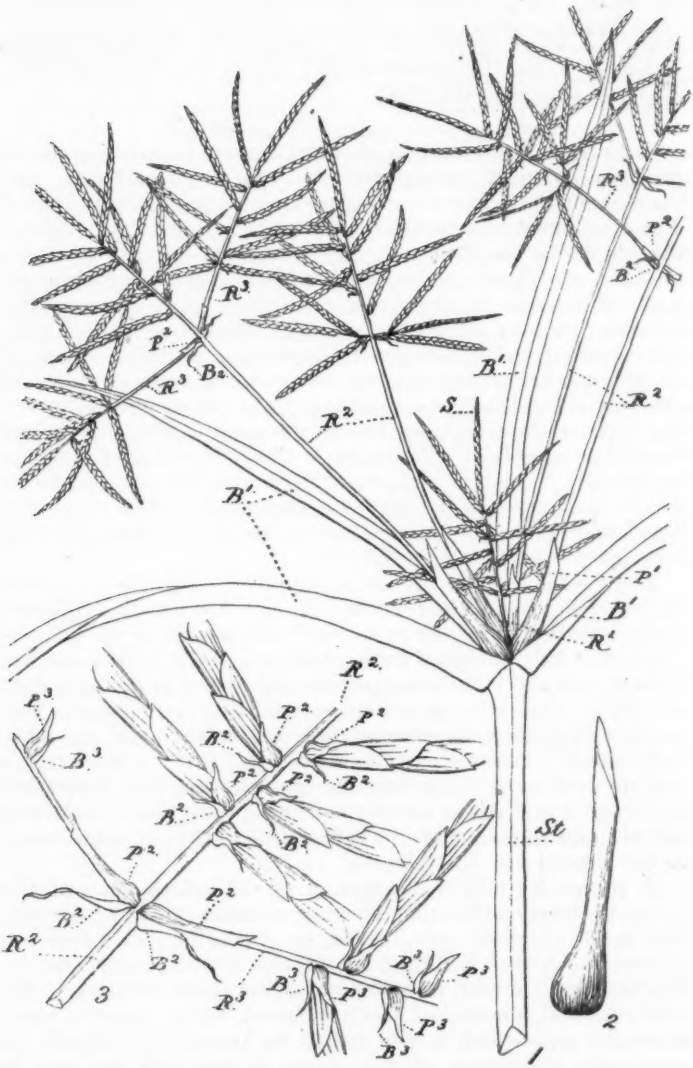

FIGURE 1. Inflorescence of *Cyperus phymatodes*, natural size.
FIGURE 2. A prophyllon from the base of a secondary ray of same magnified.
FIGURE 3. Part of the inflorescence of same, magnified. The letters are explained in the text.

ent in the inflorescence of *Cyperus*, are, to some extent, also observable in the panicle of certain *Gramineæ*.

Among the species of *Cyperus*, in which the inflorescence is ample and in which all the foliar organs are well developed and easily distinguishable, *C. phymatodes* Muehl. may be used for illustrating the composition. The accompanying figure 1 represents the upper part of the flower-bearing stem (St.) with the long, leafy bracts (B^1) arranged in a whorl near the apex and supporting secondary branches or rays, as they are often called (R^2), each of which bears a tubular prophyllon or fore-leaf (P^1) at the base.

The flower-bearing stem itself is terminated by a spike (S), borne on a similar ray (R^1) with several lateral spikes besides, but of course destitute of any bract or fore-leaf, since it is terminal. Each of the axillary rays (R^2) bears one pair of nearly opposite rays (R^3), subtended by very small bracts (B^2) and provided with minute fore-leaves (P^2); above these secondary rays (R^2) there is a number of sessile spikes, of which the uppermost is the terminal. By examining these sessile spikes, magnified in our figure 3, it is readily seen that with the exception of the terminal, they are subtended by small bracts (B^2) and that each spike bears a fore-leaf (P^2); moreover this same manner of ramification becomes repeated in the minor inflorescence of third order where the branch (R^3) with its bract (B^2) and fore-leaf (P^2) bears some spikes of third order each with a small bract (B^3) and a fore-leaf (P^3) at the base.—The flower-bearing stem (St. in fig. 1.) is, thus, extended into a short and slender rhachis (R^1) above the involucral leaves (B^1) and this rhachis or ray (R^1) is terminated by a sessile spike (S), overtopping a various number of scattered, sessile and simple spikes, all of which are lateral, being developed from the axils of small bracts. and each bearing a minute fore-leaf at the base. The only difference between this terminal inflorescence (R^1—S) and the larger, lateral ones depends, thus, merely upon these being supported by bracts (B^1) and by the presence of fore-leaves (P^1); these fore-leaves (fig. 2.) correspond to the so-called cladophyllla, which we have described in a paper upon *Carex*.*

This type of umbellate inflorescence is characteristic of several other genera within the order, and is well represented in certain species of *Scirpus*, *Eriophorum*, *Fimbristylis*, etc. It is, moreover, to be found in *Dulichium*, but with the difference that in this genus the inflorescence, although composed of exactly the same organs, is very long, the internodes between the leaves, which subtend the lateral rays, being developed as distinct internodes, and the subtending leaves being provided

* This Journal, vol. ii, p. 214, 1896.

with long sheaths in contrast to the umbellate inflorescence in *Cyperus* with sheathless, involucral leaves. Otherwise we find in *Dulichium*, as already described, the same fore-leaves though weakly developed, since they are hidden in the sheaths of the bracts, and have not the same function as those in *Cyperus*. The terminal inflorescence in *Dulichium* corresponds to that of *Cyperus*, but is raised high above the lateral ones, on account of these being scattered along the stem and borne on relatively short peduncles.

In speaking of the function of the clado-prophyllon in *Cyperus*, we might state at once, that it is by means of this organ that the rays of the umbel attain their more or less horizontal position. This is readily perceivable when we compare a young inflorescence with an older one. Because it is a well-known fact that before the stamens and pistils are fully developed, the rays and the spikes are all erect and congested. But a little before the flowers are ready for fecundation the rays spread out, forcing the involucral, sheathless leaves to attain the same position, and the spikes themselves gradually bend downwards (*Mariscus*) or horizontally (*Cyperus* proper, *Pycreus* and *Diclidium*) by the swelling of the small, basal prophylla (P^2 and P^3). This movement is best noticeable in the large, tubular prophylla (P^1) at the base of the rays, and we might, thus, briefly describe the structure of these organs in order to show, how the movement takes place. The fore-leaves (fig. 2) are tubular with a short, free apex, and they show, when mature, a very prominent swelling at their base and on that face which morphologically is the dorsal; the swelling, sometimes, attains the dimensions and shape like a spur, while the rhachis itself remains slender in its entire length. It is, thus, on the dorsal face of the prophyllon that a parenchymatic tissue rapidly develops, a tissue which in most respects agrees with true collenchyma; it is composed of short, somewhat thick-walled cells without chlorophyll and no mestome-bundles are located in this tissue. The rapid growth of this particular and very local tissue naturally produces a swelling of the leaf-base, and the result is, that the respective ray becomes pushed away from the central and terminal rhachis of the main inflorescence. (R^1 in fig. 1.) Otherwise the structure of the prophyllon shows no deviations from that of an ordinary leaf-sheath.

Although the base of the ray, which is surrounded by the prophyllon, remains slender, it nevertheless possesses some layers of similar, collenchymatic tissue, the presence of which greatly facilitates the movement from the vertical to the horizontal position, forced by the increased growth of the prophyllon. The small fore-leaves at the base of the spikes

* This Journal, vol. iii, p. 429, 1897.

(P^3 and P^2) show the same structure as the larger ones, but they are more open and only tubular at their very base.

This structure of the clado-prophyllon observed in *Cyperus* is, also, to be found in that of other genera, where the function is identical, but not in *Dulichium* or in certain *Carices* where these fore-leaves are enclosed by the sheaths of the subtending bracts, and where the direction of the rhachis or peduncle remains unchanged.

It is now interesting to notice that the involucral leaves and the clado-prophylla, characteristic of *Cyperus*, etc., may be traced in the inflorescence of certain *Gramineæ*.—Several years ago, when we observed this peculiar structure and function of the prophyllon in *Cyperus*, we naturally felt induced to look for this same organ in the inflorescence of other families, wherein the branches are able to perform the same movement from vertical to horizontal in accordance with the development of the flowers. Our attention became especially directed to the *Gramineæ*, and to such genera in which the inflorescence, the panicle, is ample and rich-flowered. We had already studied the vegetative propagation of this order, the *Gramineæ*, as represented in this country, and we had observed several analogies to exist between these and the *Cyperaceæ*, for instance, the invariable presence of a fore-leaf at the base of each lateral, vegetative branch. We had, also, learned that these fore-leaves are "always" open in the *Gramineæ*, but closed, more or less tubular in the *Cyperaceæ*, a point which explains their identity with leaf-sheaths. Among the *Gramineæ* these fore-leaves (clado-prophylla) are very large and quite numerous in such genera of which the shoots are ramified, and they are readily visible, for instance in *Coix*, *Eleusine*, *Panicum*, *Munroa*, and many others. But if we wish now to demonstrate their presence in the inflorescence also, we are obliged to admit that we have, so far, not succeeded in finding them developed as "free" leaves in any of the numerous species which we have examined for this special purpose. The large and open panicle of several species very often exhibits the presence of rudimentary bracts subtending the lateral branches, but these branches themselves do not possess an independent leaf at their base, which might correspond with the tubular prophyllon (P^1) of *Cyperus*; all that is to be seen is a small cushion-like body, which is located at the base of the secondary branches, and on that side of the branch which turns away from the mother-axis. It is, nevertheless, the peculiar structure of this little body which enables the lateral branches to spread out at a certain stage of the flowering period, and considering the fact that its position answers exactly that of a prophyllon, besides that the bract, which subtends the branch, is, also, present as

a mere rudiment, we have felt inclined to consider these organs: the cushion-like body in the *Gramineæ* and the tubular prophyllon (P^1) in *Cyperus*, as probably being identical formations.

That the bracts, corresponding with the involucral leaves (B^1) in *Cyperus*, may be observed in the Gramineæ, has been mentioned by some European agrostologists, and they are quite often developed to such extent that their sheath and blade may be distinguished. In a number of species of *Festuca*, *Bromus*, *Schedonorus*, etc., these little bracts are very distinct, at least at the lower secondary branches of the panicle, but they are seldom free, i. e., the sheath and the apex is mostly adnate to the subtended branch. However in *Panicum proliferum* we have observed one instance where the lowermost bract was provided with a free blade about 20^{mm} in length. The structure of this little bract varies within the respective genera, and may prove useful to the distinction of species, as shown by Lange in *Schedonorus*. But in regard to the supposed clado-prophyllon in the panicle of *Gramineæ*, we have not succeeded in detecting any case where this was developed as an open or free leaf, as are the prophylla of the vegetative branches in this same family. However we have noticed some points in their structure which tend to support our opinion about their real morphological identity, that they represent leaves: "fore-leaves."

These organs are quite large in *Zizania aquatica*, and we have seen one case, where one of these cushions was extended into two free tips, simulating the bidentate apex of a prophyllon. It is, furthermore, to be pointed out that in numerous species, and of the most diverse genera, the external structure of these bodies is like that of the leaf-sheaths: when the stem-leaves, and particularly the sheaths, are hairy, the same kind of hairy covering seems constantly to be observed in these cushion-like organs, and when the sheaths are glabrous these organs are, also, glabrous. Another point which we think deserves notice is, that these same organs never surround the branches, but are always, as stated above, located on the upper face only of the respective branch. Their internal structure suggests that which is characteristic of the fore-leaves in *Cyperus*, since we observed a large mass of collenchymatic tissue, which was not in direct continuation with the tissues of the rhachis itself, but was distinctly separated from the peripheral circle of mestome-bundles and their continuous layers of stereomatic tissue. A series of consecutive sections taken from a secondary branch revealed the fact, that the cushion-like body, even if it be adnate to the rhachis, does not in any place constitute a regularly developed tissue as a portion of the rhachis, but that it represents something supplemental and of which the presence does not influence the structure or arrangement

of the tissues of the rhachis proper. When we compare the structure of this organ and of the rhachis with that of a rudimentary bract and the base of the panicle to which it is adnate and with which it forms one solid body, we then perceive exactly the same conditions in respect to the tissues of the bract being well separable from those of the culm, even if they are united into one body, but of two distinct structures. In other words, the internal structure of the cushion-like body resembles that of a clado-prophyllon in *Cyperus* with its large collenchymatic tissue to such an extent, that as far as concerns the structure alone the organs appear to be identical.

Furthermore when we remember that the fore-leaves of *Gramineæ* are open, the position of this little body in the inflorescence may be well comparable with one of these, since it only covers one, the upper, face of the respective branch. Finally, as we have already stated, the function is, also, the same. We, therefore, believe that the small bodies, always observable at the base of the secondary branches of inflorescences in *Gramineæ*, most distinct in large panicles, that these represent rudimentary prophylla, identical with those described above as characteristic of *Cyperaceæ*.

It would be highly desirable if American agrostologists would reëxamine these organs in our *Gramineæ*, for it may be that some genera or species exist in which they are developed somewhat further and more distinctly as foliar organs. But in regard to our own investigations, we can only say that as far as concerns "position, function and structure" these organs may be regarded as rudimentary leaves or "fore-leaves" in this particular case.

Brookland, D. C., July, 1904.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Atomic Weight of Beryllium.*—A series of very careful determinations of this atomic weight has been made by C. L. Parsons of New Hampshire College. Two organic compounds of beryllium, the acetylacetonate, $Be(C_5H_7O_2)_2$, and the basic acetate, $Be_4O(C_2H_3O_2)_6$, were used in this work, both of which are easily purified, since they can be readily crystallized from various solvents, and since they possess the additional remarkable property of subliming unchanged. The compounds, after being weighed, were treated with nitric acid in platinum crucibles, and after evaporation the residues were ignited and the resulting beryllium oxide was weighed. Seven determinations by means of the acetylacetonate gave an average result of 9·113 for the atomic weight (where O = 16, H = 1·008, C = 12·01), while nine determinations with the basic acetate gave exactly the same average. The maximum and minimum results were 9·142 and 9·081. The results agree very closely with the atomic weight 9·1 adopted in the "International" table.—*Jour. Amer. Chem. Soc.*, xxvi, 721. H. L. W.

2. *Connection between the Volatility of Compounds and the Forces at Play within the Molecule.*—The view has been brought forward by Geoffrey Martin that chemically unstable compounds are, as a class, characterized by their volatility and fusibility; chemically stable compounds by their involatility and infusibility. For example, $SiCl_4$, BCl_3, $AlCl_3$, $SnCl_4$, etc., are all volatile and also easy to decompose, while the corresponding oxides are far less volatile and less easily decomposed. It is pointed out, further, that high valency compounds are usually more volatile than the corresponding compounds of lower valency; for instance, $SbCl_5$ is more volatile than $SbCl_3$. This behavior is regarded as due to the greater intensity of chemical forces in the lower valency compounds, as compared with the others. It seems, therefore, that it is the internal chemical forces which the atoms exert on each other in the molecule which decide the external attractive force with which the molecules themselves are attracted together, and, therefore, the volatility of the compound. The author believes that the chemical forces within the molecule determine also the solubility, fusibility, hardness, etc., of compounds, and that if these forces were known it might be possible to calculate mathematically the physical properties of chemical compounds.—*Chem. News*, lxxxix, 241. H. L. W.

3. *Method for the Determination of Chloric Acid.*—This determination is usually carried out by reducing the chlorate to chloride and determining the latter by Volhard's volumetric method. The reducing agents heretofore used have been various ones, such as zinc in some form, ferrous sulphate, etc. Hendrix-

SON has found that metallic iron in the form of "card-teeth" in the presence of 10 per cent sulphuric acid effects this reduction rapidly at ordinary temperatures. At first ferric salts are formed and give the solution a yellow color, but these salts are soon reduced and the solution becomes colorless or slightly green. The reduction requires about one hour at room temperature. The process is applicable to bromates, while perchlorates are not reduced by the operation and hence do not interfere with it. Test-analyses are given which show excellent results, and it appears that the method is a very simple and convenient one.—*Amer. Chem. Jour.*, xxxii, 242. H. L. W.

4. *The Investigation of Double Salts by the Determination of Solubility.*—As a continuation of work by the method devised by Professor Foote of the Sheffield Scientific School, FOOTE and BRISTOL have found that barium and mercuric chlorides, below 17·2°, form the double salt $BaCl_2 \cdot 3HgCl_2 \cdot 6H_2O$. Above this temperature no double salt can be crystallized, although there is evidence that combination takes place in solution, because the solubility of each salt is largely increased by the presence of the other. The double salt thus found is a new one. A compound, $BaCl_2 \cdot 2HgCl_2 \cdot 2H_2O$, described by Bonsdorf about seventy-five years ago, does not exist, at least at 10·4°.

FOOTE has found also that the remarkable double nitrate, $2KNO_2 \cdot Ba(NO_2)_2$, described a year or two ago by Wallbridge, is a true double salt, capable of forming under a rather wide range of conditions. He has shown also that no double salt is produced by potassium and barium chlorides at 25°, although the combination of chlorides is far more usual that that of nitrates.—*Amer. Chem. Jour.*, xxxii, 246; 251. H. L. W.

5. *Nitrous Anhydride.*—It has been known for a long time that mixtures of the gases NO and NO_2 condense to a blue liquid, and it has been shown by Lunge and Porschnew that at –20° the composition of the blue liquid formed by saturating liquid N_2O_4 with gaseous NO corresponds very closely to the compound N_2O_3, or nitrous anhydride. This blue compound, consequently, has been regarded as nitrous anhydride, but up to the present time it has not been shown that the compound exists in the solid state, nor that it is the only compound of the two gases. WITTORFF has recently made fusing-point determination with known mixtures of N_2O_4 and NO, and has found that N_2O_3 exists in the form of blue crystals which melt at –103°, and that no other compound was formed at the temperatures used in the experiments.—*Zeitschr. anorg. Chem.* xli, 85. H. L. W.

6. *A Probable Cause of the Yearly Variation of Magnetic Storms and Auroræ;** by Sir NORMAN LOCKYER and WILLIAM J. S. LOCKYER.—The ordinary meteorological elements, such as atmospheric pressure, temperature, etc., have a yearly change

* From the Proceedings of the Royal Society of London, lxxiv, 90.

satisfactorily explained as due to changes of the position of the earth's axis in relation to the sun, or, in other words, the variation of the sun's declination. There are, however, other phenomena, such as magnetic disturbances and auroræ, which have been explained differently.

Thus, in regard to this seasonal variation Mr. Ellis* has written, "The related physical circumstance is that at the equinoxes, when disturbance is more frequent, the whole surface of the earth comes under the influence of the sun, whilst at the solstices, when magnetic disturbance is less frequent, a portion of the surface remains for a considerable period in shadow."

The object of the present communication is to put forward another possible cause.

It has been previously pointed out† that a very close relationship exists between the epochs of occurrence of prominences in the polar regions of the sun and Ellis's "great" magnetic disturbances. This synchronism showed that either the polar prominences themselves, or the disturbances thus indicated in these polar regions, were the origin of these "great" magnetic storms, or that they were caused by a more general stirring-up of a greater extent in latitude of the solar atmosphere.

A further investigation‡ indicated, however, that in all probability it was either the actual polar prominences themselves, or the activity in the solar polar regions, that initiated these magnetic disturbances, for it was there pointed out that the presence of polar prominence activity-tracks synchronized with the appearances of large "polar" coronal streamers. Here we have an indication of a local cause and effect.

It will be gathered then, that, even as regards terrestrial magnetic phenomena, considerable importance must be attached to action taking place in the regions about the solar poles.

Since the axis on which the sun rotates is inclined to the plane of the ecliptic, there will be times throughout the course of a year when the solar polar regions will be exposed most and least to the earth.

It should be expected, then, that if the polar regions of the sun have any action, as above suggested, the effects of the action on the earth should vary according to the positions of the solar poles relative to the earth.

The actual inclination of the sun's axis being 82° 45′, and the longitude of the ascending node being 74° 25′, or the tilt of the axis being in the direction of about 19 hours in right ascension, it follows that, in each year, the south pole of the sun is most turned towards the earth in the beginning of March (about the 6th), and the north pole most towards the earth in the beginning of September (about the 5th). At the two intermediate epochs,

* Monthly Notices, vol. lxi, p. 540.

† Proc. Roy. Soc., vol. lxxi, p. 244; also Monthly Notices, R.A.S., vol. lxiii, Appendix I, p. 6.

‡ Monthly Notices, R.A.S., vol. lxiii, p. 481.

in June (about 5th) and December (about 6th), neither pole is turned towards or away from the earth, but occupies an intermediate position. Hence we see that the equinoxes occur in the same months as those in which one or other of the solar poles is turned towards the earth, while the neutral positions of the solar poles in relation to the earth occur in the same months as the solstices.

The accompanying diagram [here omitted] shows graphically the relation between the two curves representing the variation of the sun's declination and the change of the latitude of the sun's center or the variation of the amount of the tilt of the solar poles, in relation to the earth throughout a year.

It will be seen that the curve representing the tilt of the solar axis is nearly (a little less than) a quarter of a phase in advance of that indicating the declination change, so that the maximum or minimum point of the latter curve is only slightly in advance of the *mean* points respectively of the former curve.

If, therefore, these solar polar regions are capable of disturbing the magnetic and electric conditions on the earth, as has been above suggested, then, when they are most directed to her at the equinoxes, the greatest effects during a year should be recorded, and when they are least directed the effects should be at a minimum.

It will not be necessary here to refer at any great length to statistics relating to the annual inequality of magnetic disturbances and auroræ, for these have been very efficiently worked out and the results published by Mr. William Ellis.*

Mr. Ellis has shown that the curves of frequency of magnetic disturbances at Greenwich and Paris are very similar, "showing maxima at or near the equinoxes, and minima at or near the solstices." These also, he further points out, are similar, with regard to the epochs of maxima, to the curve representing the frequency of the aurora at London. In the case of auroræ observed in Edinburgh, Northeast Scotland and in different regions in Scandinavia, the months in which the greatest frequency is recorded are September and October (perhaps more generally October) and March and April (perhaps more generally March). Mr. Ellis is inclined to the opinion that there is a small tendency for the autumn maximum to become a little later (from September to October) and the spring maximum somewhat earlier (from April to March) as higher latitudes are approached.

Further, he points out that in more northern latitudes the mid-winter minimum of lower latitudes appears to diminish and eventually disappears, so that the curve of frequency of the aurora between October and March is practically flat with a small intermediate maximum about January. This change in form of the frequency curve in regions in close proximity to the

* Monthly Notices, R.A.S., vol. lx, p. 142; vol. lxi, p. 537; vol. lxiv, p. 229.

magnetic pole, and where the conditions of day and night are so different, is of great interest, but requires careful consideration before it can be regarded as representing real auroral changes.

The accompanying curves [here omitted] illustrate the relation throughout a year between the positions of the earth's poles with reference to the sun ; the positions of the sun's poles as regards the earth ; the frequency of magnetic storms at Greenwich and Paris ; and lastly, the frequency of the aurora as observed at Edinburgh and at stations in Scandinavia below latitude 65° N. The first two curves are those that have already been mentioned, but plotted differently. They have here been so arranged that the maxima points represent the epochs when each of the poles is most inclined to the sun or earth as the case may be. Both the magnetic and auroral curves represent four of the set of curves which Mr. Ellis* has recently published.

It need scarcely be pointed out that the low minima of the auroral curves during the summer months are due in great part to the shortnesss of the nights, and therefore to the restriction of the time available for aurora observations.

The coincidence in time between the epochs of the maxima of the frequency of magnetic disturbances and auroræ, and those of the greatest inclination towards the earth of the north and south solar polar regions is clearly indicated.

It is interesting to inquire in what way this yearly inequality of terrestrial magnetic phenomena is influenced when the sun's polar regions are, for different groups of years, in an undisturbed and disturbed condition.

It would be expected that the oscillation of more disturbed solar polar regions towards and away from the earth would tend to *increase the difference* between the frequency of magnetic disturbance at the equinoxes and solstices, while this difference for those years when the less disturbed solar polar regions are in action should be somewhat *reduced*. That this is actually the case is brought out by the figures which Mr. Ellis has given in the publication of which mention has already been made.

Since the greatest magnetic storms are closely associated in point of time with prominence disturbances in the polar regions of the sun, to make the necessary comparison, therefore, the years in which "great" magnetic storms occurred should be grouped together and the yearly inequality determined, and another group of years in which "great" magnetic storms were less frequent formed and the yearly inequality also determined. Fortunately a computation already made can be utilized for this comparison, for Mr. Ellis has determined the number of days of greater frequency (near sunspot maximum), and lesser frequency (near sunspot minimum), of magnetic disturbance, both groups practically including the conditions required. Thus he has formed groups of the years 1848–51, 1858–61, 1869–72, 1882–85, 1892–95, which include, at any rate for the last three groups, the years where

* Monthly Notices, R.A.S., vol. lxiv, p. 229.

prominences were in high latitudes, and another series of groups of years, 1854–57, 1865–68, 1876–79, 1887–90, which are years when prominences were less frequent in these regions.*

The interesting conclusion to which Mr. Ellis arrived was that "the excess of the equinoctial frequency over the solstitial frequency is greater, the greater the degree of disturbance."

This result thus helps to endorse the suggestion made in a previous paragraph that the greater the disturbed solar polar regions, the greater the difference between the magnetic frequency at the equinoxes and solstices.

Conclusions.—The conclusions arrived at in the above paper may be briefly stated as follows:

1. The seasonal variation in the frequency of magnetic storms and auroræ depends on the position of the sun's axis in relation to the earth.

2. The epochs of the greatest inclinations of the sun's axis towards or away from the earth, or in other words the greatest exposure of the N. or S. solar polar regions to the earth during a year, correspond to those of greatest magnetic and auroral frequency.

3. The epochs (groups of years), when the solar polar regions are most disturbed, synchronize with those when the excess of the equinoctial over the solstitial frequency of magnetic storms is greatest.

7. *Physikalische Technik, oder Anleitung zu Experimentalvorträgen sowie zur Selbstherstellung einfacher Demonstrationsapparate.* Seventh Edition. By Dr. Otto Lehmann. Pp. xx + 630. Braunschweig (Friedrich Vieweg und Sohn).—This is the first part of volume one of Dr. Joseph Frick's well known work. In this edition the book has been entirely rewritten and very much enlarged. In its present form it is an exhaustive compendium treating of the objects, methods and materials of the experimental lecture as a branch of instruction in Physics. This part of the work is concerned with the arrangement of the lecture and preparation rooms and the workshop. All the details of the installations for the electric, gas, water, steam, air pressure and vacuum services and all the non-portable parts of the lecture-room outfit are gone into with the greatest thoroughness. The portion on the shop will be of value to the worker in the laboratory as well as to the lecturer. This part occupies nearly half the book and contains numerous methods, recipes, etc., of use

* The fact that continuous observation of solar prominences was only commenced in 1870 accounts for our lack of knowledge of the frequency of this class of phenomena before that date. Since, however, during the last three sunspot cycles it has been observed that polar prominences are most frequent just a little after a sunspot minimum and up to and at the epoch of the following sunspot maximum, it may be concluded that their appearance previous to the year 1870 occurred at the same time in relation to the sunspot cycle. Ellis's groups of years previous to that date, namely, 1848–51 and 1858–61, may on these grounds be classed as years in which polar prominences were present, whilst the groups 1854–57 and 1865–68 may be taken as epochs when polar prominences were not so frequent.

to the instrument builder, as well as instruction in the arts of forging, soldering, glass-blowing and cutting, lacquering, etc. In addition there are many useful hints on the working and handling of materials such as quartz, amber and porcelain. The camera and dark-room as adjuncts of the lecture, especially the making of slides and the art of photo-micrography, are extensively treated. In fact, one can hardly think of anything in the organization and equipment for this side of physical instruction, from the clerical work of the office to the chemical room, that is not treated. Altogether this is a most valuable book. L. P. W.

II. Geology.

1. *Recent Studies of the Moon's Features* (Communicated by J. Barrell).—Within the past year have appeared two notable contributions to the literature of the moon's surface. One is by Professor N. S. Shaler,* the other by Professor W. H. Pickering† and they represent divergent views. Professor Shaler remarks in the Preliminary Note: "The ends sought have been those alone which had distinct reference to geology. . . In fact almost all the questions brought up by studies on the satellite are more or less entangled with those relating to the evolution of the planet, so that except for the detailed account of the features of either body they must needs be considered together. These features may be compared by types, and in the main the following essay consists of such comparisons."

The craters are so different in size from those of the earth, many being over a hundred miles in diameter, and so numerous, overlapping and irregularly distributed that the causes leading to their formation must be very different from those of volcanoes upon the earth, and for these forms Shaler proposes the name of vulcanoids. The maria, or great plains, evidently belong to a category distinct from the vulcanoids, being characterized by their larger size, smoother and darker floors, and it is suggested that they may be caused by the infalling of large meteors. It would seem, however, that the attempt to provide a meteoric origin for the maria, but not for the craters, would lead into grave difficulties. While the evident fluidity of the lavas which formed them distinguishes them sharply from the steep, rough walls of the vulcanoids, yet in degree of fluidity and in area covered they have not so far exceeded the great lava flows of the western United States and the Deccan of India. The mountainous reliefs

*A Comparison of the Features of the Earth and the Moon, by N. S. Shaler, Professor at Harvard University. Smithsonian Contributions to Knowledge, vol. xxxiv, 79 pp., 24 plates.

† "The Moon, a Summary of the Existing Knowledge of our Satellite, with a complete Photographic Atlas," by William H. Pickering of Harvard College Observatory. 103 pp., 100 plates. New York, Doubleday, Page & Co. The text is a semi-popular treatment of matter already published in vols. xxxii, part I, 1895, part II, 1900 and vol. li, 1903 Annals of the Astronomical Observatory of Harvard College.

are classed under a number of heads, certain wrinkles upon the surfaces of the maria appearing to correspond to the usual earth type of mountains due to crustal shortening; the other types appearing to have had an igneous origin and to be formed of viscous lavas which have solidified with very steep slopes. Clearly marked faults are rare upon the moon, though cracks, as indicated by the so-called "rills," are abundant.

The almost complete absence of evidence of shrinkage and consequent tangential or mountain-making thrust is one of the greatest fundamental distinctions between the history of the earth and its satellite and for a better understanding of which we may have to await a fuller knowledge of the causes of terrestrial contraction.

The ray systems, whitish streaks which radiate from certain of the prominent craters to distances of several hundred miles, crossing plains and vulcanoids alike, are among the most enigmatical features of the moon's surface, becoming strongly visible only about two days after sunrise and disappearing at a somewhat lesser interval before sunset. The author concludes that they are probably fumarolic deposits within and upon the crust from extremely deep-seated fissures and that they are of ancient origin, a view which precludes their consisting of ice, since in that case a gradual evaporation and dispersal of the water vapor would take place at even the lowest temperatures. They are regarded as most probably due to some crystalline and fluorescent material which does not reflect the sunlight until a considerable elevation has been attained.

Considering that these ray systems are of considerable geological antiquity, the author raises the question as to why in a sphere free from erosion they have not become veiled by meteoric dust. Of a number of suggestions presented to explain this feature the most reasonable are that either the amount and importance of meteoric dust received by the earth and moon have been greatly overestimated, or else that we have misjudged the age of the moon's surface and the ray systems are not of great antiquity.

As to the permanence of the lunar relief, it is evident from an examination of the plates "that there is some agent which has operated to break down the more ancient topographical features. There is an evident difference of aspect between the walls of the older vulcanoids and those of newer formation." In fact all stages of obliteration may be traced to large nameless vulcanoids whose ruins only a careful examination will reveal. As water has evidently never acted, the most probable cause is assigned to be alternate expansions and contractions of the superficial crust during the lunar day and night. Whatever the agent of decay may be, the numberless superpositions of vulcanoids and the extremely ruined character of the most ancient is indicative of a long and complex volcanic history. Professor Shaler as the result of his studies disbelieves in any atmosphere or present volcanic activities even of solfataric stages, but in view of the

recent studies to be mentioned later these views may be too extreme. In regard to the question of vegetable life upon the moon it is very properly stated that other possible explanations should be sought to account for the darkening of certain areas at lunar midday in preference to believing them due to vegetable growth. Against the existence of even vegetable life upon the moon it is urged that no terrestrial life exists upon mountain slopes 20,000 feet or more above the sea under atmospheric and thermometric conditions which must be vastly more favorable than those to be found upon the moon. Furthermore, whatever were the circumstances, as yet unknown, which led to the beginning of life upon this earth, they were evidently of rare occurrence. "The fate of our satellite was probably in large part determined by the ratio between its gravitative force and the energy of the kinetic movement of the gases such as constitute the atmosphere. If that energy had been sufficient to retain them on the satellite, there is no reason, at least so long as the original rotation on its axis continued, why it should not have had the history of a miniature earth."

The plates are from photographs in the possession of the Smithsonian Institution and have been taken at the Lick, Paris, and Yerkes Observatories. They are all extremely fine reproductions on several different scales selected with reference to the questions discussed in the text and may be considered as a separate contribution by the Smithsonian Institution to Selenography.

"The Moon," by Professor Pickering, although written in a popular manner, is issued as a scientific book intended for an intelligent class of readers who are not astronomers, and it must be criticized on that basis.

The first three chapters present the commonly accepted views as to the origin of the moon, the data in regard to its distance, rotation, etc., and views arrived at within a few years by the writer and others regarding the density and temperature of a lunar atmosphere.

In another chapter under the subject of artificial craters, the author cites the blow holes formed on the surface of pots of solidifying slag, and also gives the results of experiments upon paraffin, especially where a pumping motion was given to the still molten portions beneath the solidifying crust to simulate subcrustal tidal waves. By this means he was able to obtain the appearance of lunar craters. It may be remarked, however, that even if the craters were all made during that distant time when the moon still retained an axial revolution faster than its orbital revolution about the earth, a conclusion which Pickering himself apparently does not accept, it would be impossible for a solid crust to maintain such rigidity that the lava communicating with a molten interior could rise and fall to an appreciable extent through tidal action. On the contrary, as in the case of the earth, the whole spheroid would yield. This weakness is pointed out by Professor Shaler. The hypothesis is furthermore based

upon the old idea, of an outer crust and a fluid interior, though it has never yet been proved that at any time in the cooling of a planet would such conditions exist.

As it would appear impossible, therefore, to account for the lunar craters by a hypothesis of tidal action upon a fluid interior, it must be confessed that their fundamental differences point to an origin unlike any volcanic features of the earth, and we are still far from an understanding of them.

Under the subject of active lunar craters and river beds, the author describes changes which have been observed in certain lunar craters, which have led him to the belief that volcanic activity has not ceased upon the moon, and that water vapor which immediately turns into clouds of hoar frost is given off from certain craters. In the following chapter it is maintained that the greater brightness of many crater rims and likewise the bright streaks radiating from a number of the principal craters consist of snow.

In the earlier chapter upon the lunar atmosphere, water, and temperature, the author gives good observational grounds for believ ing that an atmosphere exists at the moon's surface, comparable in density to that of the earth at a height of from 40 to 45 miles above the surface. In addition, a haze appears to rise to a height of from three to four miles upon the sunlit side of the moon, but is absent from the unilluminated portion.

Accepting the facts of observation, the extremely questionable side is in the interpretations given them. It has been shown by Stoney that water vapor would escape with great rapidity from the moon and carbon dioxide somewhat more slowly. It would seem extremely improbable, therefore, that these two gases should at the present time be undergoing elimination from the body of the moon, at such a rate as to constitute even such a rare atmosphere as is found or permanent snow fields. Such a hypothesis, while explaining with apparent satisfaction the observed enlargement of the white spots of Linné toward lunar sunset and during a lunar eclipse, as due to a sublimation of hoar frost, is peculiarly difficult of application to the system of rays, and both the atmosphere and rays may consist of some other substances. Until some means is found of proving their nature, some of the suggestions offered by Professor Shaler would appear more reasonable.

Finally in the chapter upon "*Vegetation: the Lunar Canals*," the writer gives his reasons for believing that a luxuriant vegetation exists upon the moon. The evidence for this extreme view is based entirely upon the darkening of certain areas, and their increase of size during the lunar morning, and their disappearance shortly before the time of sunset.

Since conditions so unfavorable to life exist upon the moon, the hypothesis of vegetation should apparently be the last to be sought as an explanation for these mystifying phenomena. An outline of Professor Shaler's criticisms has already been given, and it may be said in addition that for any form of lunar life to

exist not only would it have to originate and evolve into something higher than primordial forms under atmospheric conditions incompatible with life as we know it, but that the conditions of temperature would likewise appear to preclude such a view. While our knowledge of lunar temperatures has been in times past very imperfect, it may be well to quote Professor Very's* more recent and carefully ascertained results. "In conclusion, it seems to me reasonably certain that a large part of the Moon experiences daily great vicissitudes of temperature. Its rocky surface at midday, in latitudes where the sun is high is probably hotter than boiling water; and only the most terrible of Earth's deserts, where the burning sands blister the skin, and men, beasts, and birds drop dead, can approach a noontide on the cloudless surface of our satellite. Only the extreme polar latitudes of the moon can have an endurable temperature by day to say nothing of the night, when we should have to become troglodytes to preserve ourselves from such intense cold."

Although as Professor Very remarks, the noontide temperature may be lower and the life conditions in that regard possibly more favorable than if the moon possessed an atmosphere comparable to our own in density, scientists in general and biologists in particular will be loath to accept a belief in life of any sort upon the moon until at least all other and inorganic hypotheses have been exhausted.

It is regretable that when a scientific volume is put forth for a public who are not specialists, that such doubtful interpretations should be stated as though they were well established and well accepted scientific truths.

The plates show in a systematic manner all visible portions of the moon's surface under five different degrees of illumination, on a scale of $5'' = 1^{mm}$, giving a lunar diameter varying from 14 to 16 inches. As pointed out on p. 97, this is the only complete photographic atlas of the moon in existence, and not only so but it covers the whole visible surface of the moon five times. As the scale is rather small, however, the plates are chiefly useful in studying general features of the moon.

2. *Cretaceous Deposits of the Pacific Coast;* by FRANK M. ANDERSON. Vol II, No. 1, 3d Series, California Academy of Sciences, 146 pp., 12 pls.—The Cretaceous deposits of the Pacific Coast of North America lie within a narrow continental border mainly to the west of the Great Basin and the northern Cordillera. Southward the only deposits of the Pacific province known are isolated ones in Mexico and Chili. In the description of these beds there are given for the first time in a connected account the essential faunal and physiographic facts. The divisions recognized in the Sacramento Basin are:

(1) The Knoxville horizon, several thousand feet in thickness and extending to the upper limit of known species of *Aucellas*,

* The Probable Range of Temperature on the Moon, The Astrophysical Journal, vol. viii, Dec., '98, p. 286.

the fauna being essentially boreal. (2) The Horsetown horizon, beginning with the close of the Knoxville and continuing to the horizon representing the great Chico overlap, the fauna being typically subtropical. (3) The Chico or uppermost member as represented by the Phoenix beds, and by those of Wallala and other points in Lower California. The Chico is divisible into two horizons in the Sacramento Basin, and perhaps elsewhere, the later Chico fauna being characterized by a large development of gasteropods and lamellibranchs.

The general order of regional movement, more particularly in the Great Valley, has been downward from the first, but not continuously so. The different members of the Cretaceous series of California find their counterparts all along the American border of the Pacific, and are to be closely correlated with the recognized members of the interior basins of both hemispheres, as shown by a parallelism of crustal movement and development much more general than commonly supposed, and by extensive faunal resemblances, amounting often to close specific affinity or even specific identity. The faunæ of the Pacific coast Cretaceous are mostly marine, and of littoral rather than deep-sea origin. G. R. W.

3. *Geology of German Southwest Africa.* — At a meeting of the Geological Society of South Africa, held at Johannesburg, July 11th, 1904, Mr. F. W. Voit presented a paper on the geology of the region east of Walfish Bay and between the Quisep and Swakob Rivers.

The country is in large part desert, covered with quicksands and sand dunes. The greater part of the country exhibits the same geological features as the oldest members of the geological formation in South Africa. The base of the district consists of schistose rocks, exhibiting large variety ranging from fine schists to coarsely banded gneisses. These metamorphic rocks are ascribed to the Archean Period. The amphibolite layers in the gneisses are believed to be extrusives of a diabase type. There are also intrusive masses of granite. A few outcrops of sandstone occur and are classed as Lower Devonian. The appearance of copper ore in this district has been investigated by Mr. Voit, and it seems probable that extensive deposits of medium grade ore will be found. It is of interest to note that volborthite (which is elsewhere a rare mineral) is of very frequent occurrence in this district. The rocks collected have been studied microscopically by Professor Beck, of Freiburg.

4. *Liassic and Oolitic Floras of England.*—Being Part II of the Jurassic Flora represented in the British Museum ; by A. C. Seward. 183 pp., 13 pls.—This number of the British Museum catalogue forms the completion of a treatise on fossil floræ of the Trias, Rhætic, Lias, and Oölite of England. Although the fossils included in Part II are for the greater part fragmentary, the high degree of care bestowed on this as on all the parts gives the descriptions importance in themselves aside from the fact that they belong to a series that is indispensable to every student of fossil plants and plant distribution.

Among special features of Part II there perhaps only needs to be here mentioned the fact that two small leaves with a decidedly dicotyledonous appearance are figured (Plate XI, figures 5 and 6) from the rocks of the Great Oölite of Stonesfield, as belonging to the "convenient genus" *Phyllites*. This Seward would have restricted for the designation of Dicotyledonous leaves that cannot with certainty be referred to a particular family.—In commenting on the extremely scanty occurrence of Jurassic dicotyls Seward says, and the reviewer has similarly expressed himself,—"There is, in short, no *à priori* improbability that Dicotyledons existed ages before they attained to a position of importance, and it is highly probable that this was the case." The fundamentally important statement is also made that, "We cannot deduce any evidence from such data as we possess in favor of the existence of well-defined botanical provinces during the Rhætic, Jurassic, or Wealden periods." G. R. W.

III. Miscellaneous Scientific Intelligence.

1. *British Association.*—The annual meeting of the British Association for the Advancement of Science was held at Cambridge during the week from the 17th to the 24th of August. The inaugural address upon the subject* "Reflections suggested by the new Theory of Matter" was delivered by the President, the Right Hon. A. J. Balfour. The attendance at the meeting was 2,789, which has only been exceeded on five occasions. The meeting of next year is to be held at Cape Town, South Africa, and Dr. George H. Darwin has been elected President.

2. *The Metric Fallacy;* by Frederick A. Halsey. *The Metric Failure in the Textile Industry;* by Samuel S. Dale. Pp. 231. New York, 1904 (D. Van Nostrand Co.).—This is a somewhat caustic arraignment of the metric system based upon a paper presented to the American Society of Mechanical Engineers in December, 1902. The authors claim that the actual introduction of the system, in countries where it is sanctioned by law, is less complete than has been supposed, from the standpoint of its practical application in the arts, and give reasons why they believe its introduction in this country to be undesirable.

Scientific workers believe strongly in the simplicity and value of the metric units, but it is fair that the subject should also be discussed from the standpoint of its practical application to the useful arts.

Obituary.

Dr. Joseph D. Everett, for upwards of thirty years Professor of Natural Philosophy at Queen's College, Belfast, died on August 9 at the age of seventy-three years. His excellent translation of Deschanel's Natural Philosophy has been long known and highly valued by students of physics. His book on the C. G. S. system of units, published when the selection of practical units in electricity was under discussion, was an important contribution which has had a wide influence. He was also the author of numerous papers, largely on theoretical subjects.

* See Nature for August 18, also the same number and those immediately following for the addresses by the Presidents of Sections.

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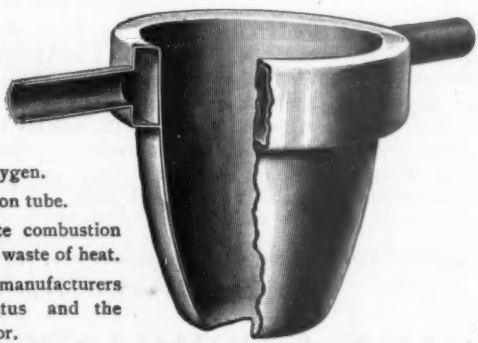

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